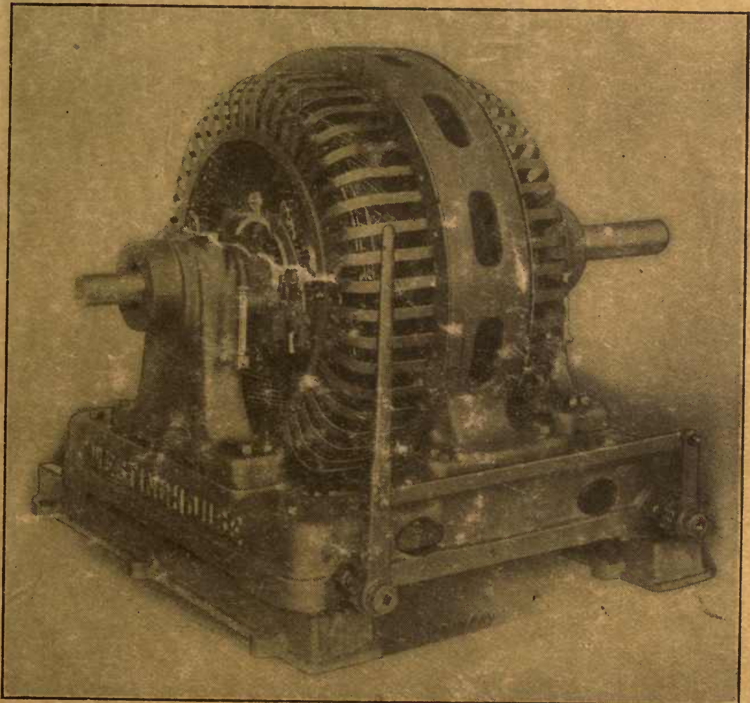
CENTS

CARE OF DYNAMOS AND MOTORS

THIRD REVISED AND ENLARGED EDITION



MACHINERY'S REFERENCE BOOK NO. 34
PUBLISHED BY MACHINERY, NEW YORK

MACHINERY'S REFERENCE SERIES

EACH NUMBER IS ONE UNIT IN A COMPLETE LIBRARY OF MACHINE DESIGN AND SHOP PRACTICE REVISED AND REPUBLISHED FROM MACHINERY

NUMBER 34

CARE AND REPAIR OF DYNAMOS AND MOTORS

THIRD EDITION—REVISED AND ENLARGED

CONTENTS

CHAPTER I

THE OPERATION AND CARE OF SMALL ELECTRICAL MACHINERY*

As the majority of users of small electrical machinery are not familiar with the best methods employed to keep the machines in good running order and repair, the author aims to present a few practical suggestions, to be of some help in the making of necessary repairs, locating troubles, and removing the causes.

The dynamo or motor should be installed in a dry place, and under no circumstances should water be allowed to come in contact with the machine. Excessive dampness always causes trouble, and this point should be guarded against. The machine should be well ventilated, and kept free from dust as much as possible. Before starting a new machine, see that the bearings are well filled with good oil, and that the shaft turns freely in the bearings. The oil-rings should turn with the shaft, and not stick, as the lubrication of the bearings depends upon the rings working right. This is important and should be carefully watched. If the machine is belt driven, the belt should not be too tight, as this will cause undue wear on the bearing and may cause heating also. Always provide solid foundations or supports for the machine to rest on. Keep the machine cool, dry and clean, and very little trouble will result in its operation in general.

When a new machine is installed and wired up, the connections should be carefully checked over to see whether they correspond with the diagram of connections sent with the machine. If this is found to be correct, and the machine refuses to act properly, the cause of the trouble should at once be located and the difficulty removed before going further.

Troubles in the Field Coils

First we will consider the troubles that may exist in the field coils, and how to proceed to correct them. If, on running a machine for some time, the field coils all become hot, the voltage may be too high and should be reduced to normal. If only a part of the coils becomes hot, it will usually be found that a connection exists between the coils and the frame of the machine (called "ground"), which when found should be insulated with mica or paper. Sometimes it will be found that some of the coils are cold while the remainder are excessively hot, and the cause of this is a short circuit in the cold coils, which means that the current is not passing through the coils. Test out the coils separately with a magneto or battery, and when the defective coil is found, it should be repaired by reinsulating it.

A partial short circuit will cause the coils to heat, and should be

* MACHINERY, March, 1910.

treated as stated above. In a compound-wound machine, *i. e.*, one having a shunt and series winding on the field coils, an over-load will cause an excessive current to flow through the series coils, causing the heat to rise above normal. The load should be reduced or a "shunt" should be connected as shown in Fig. 1. This will cause the current to divide, part of it flowing through the shunt, thereby reducing the heating of the series coils.

If a machine is run as a generator and will not generate the rated voltage, that is, if it shows too low voltage, or if the speed is too high when run as a motor, the cause may be a loose field connection, which should be carefully traced and tightened. Any extra resistance in the field will cause a motor to speed up, and the rheostat, in case one is installed, should be cut out of the circuit. The same trouble will arise

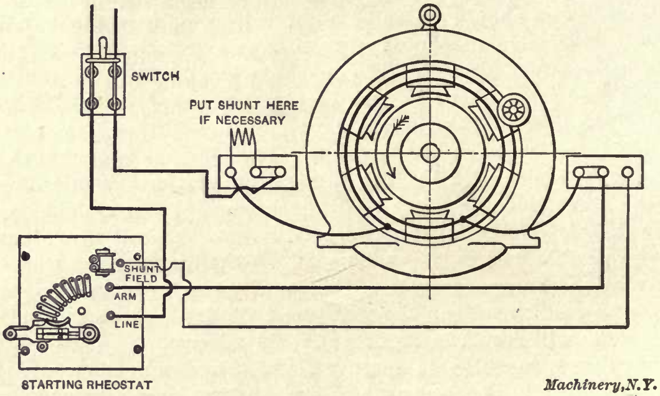


Fig. 1. Diagram showing Reduction of Over-load by means of a Shunt

from a short circuit in one or more coils, or having the polarity reversed in one or more coils. Test this with a compass, or reverse the leads of one coil. If a generator will not hold up the normal voltage when loaded, or if the speed of a motor is too high when running under full load, the series field is either cut out of circuit or is reversed and is opposing the shunt. Disconnect the shunt coils entirely and try the machine without them. If the operation is now satisfactory, reverse the leads of the shunt field, and again connect them. If the motor refuses to start, there is no current through the shunt field, and the open-circuit should be found and repaired.

In case the motor takes an excessive starting current, the series field is opposing the shunt, and one of them should be reversed. If the motor runs the wrong way, reverse the series field or reverse the shunt field, or, in a compound-wound machine, both the series and shunt fields. Never open the field circuit when the motor is running, as this would cause the machine to speed up to such an extent that the armature is liable to burst from centrifugal force. The above covers nearly everything that is due to field trouble.

Armature Troubles

When an open circuit occurs in a coil, it is shown by the broken leads, or by sparking at one or more bars of the commutator. The leads should be re-soldered into the commutator bars, or the broken wires spliced, or a new coil put in. Hot coils are caused by short circuits at the commutator or between the separate turns of the coil, in case the winding is made up of more than one turn of wire for each coil, or from the grounding of the coil to the shaft or armature core. The leads should be separated and insulated from each other, and if this cannot be done, a new coil should be put in. Sometimes there is a short circuit between the bars through the mica segment, or on the mica ring itself, and if this is the case, a new segment or ring should be put in, and the commutator turned off smooth in a lathe.

When it is found that the whole armature heats up, the cause may be that the machine is pulling a greater load than it was originally designed for, in which case the load should be reduced, or else the machine exchanged for a larger one. If a machine is run at a lower rate of speed than that at which it is intended to operate, the armature often becomes quite hot, due to excessive iron losses, which will practically disappear when the speed is brought up to normal. The entire armature is sometimes heated by "cross-currents" which are set up in the windings, due to the fact that the brushes are not set or spaced properly on the commutator. The only way to be sure that the brushes are spaced correctly is to count the commutator bars between each brush or set of brushes; this should be done as follows: Take for instance a commutator having 120 bars, and four sets of brushes. Set the first brush on any segment, and count thirty bars ahead of the bar on which the first brush is set, placing the next brush on this bar, and continuing thus around until all four brushes are placed in position. This will space the brushes equally apart, and when they are set properly, they can easily be kept in this position by making a gage of soft wire, just the length of the space between them.

To fit the brushes properly to the commutator, set them in position as nearly as possible, and place a strip of coarse sandpaper around the commutator (sand side up) and turn the armature around slowly; finish with fine sand-paper, preferably No. 00. This, of course, refers to carbon brushes only, as hardly any other kinds are now used. After the brushes have been "sanded down," the spacing should be tested again, and the brushes re-sanded if necessary. Radial type brushes should present the entire end to the commutator, and should be thus fitted. After fitting the brushes, the carbon dust should be carefully blown off the machine before starting it up. Shift the brushes to the best running position, *i. e.*, where no sparking occurs at full load, and clamp the brush holder yoke in this position, marking it in some way so that it can be set again in this position if it becomes necessary at any time to move it. Sometimes the armature becomes hot from the heat given off from a hot bearing or commutator, and as this is a purely mechanical fault, it will not be discussed here.

Heating in many cases is caused by poor ventilation, and if this is found to be the trouble, the obstruction which prevents a free circulation of air around the machine should be removed, or if this cannot be done, a small fan can be used to give artificial ventilation to the machine.

Burned-out armatures owe their destruction to one or more of the following troubles: over-load, grounded line, grounded coils, short circuit, either on the line or in the machine itself, cross-currents in the armature as mentioned before, or from lightning discharges coming in contact with the lines leading to or from the machine, or striking the machine directly, which, however, is a rare thing. The only remedy for a burned-out armature is to rewind it, or to replace the defective coils.

When a break-down of insulation occurs, a "ground" is the result, owing to the fact that a part or all of the current does not complete its circuit through the coil, but passes through the armature core and frame of the machine to the earth. If the bad place in the insulation cannot be found any other way, the leads should be removed from the commutator and tested out separately. If a lighting circuit is available, an effective test can be arranged as follows: Connect up a lamp as shown in Fig. 2 and place lead No. 1 on the shaft or other bright part of the machine; then touch lead No. 2 on each coil separately. If a coil is grounded, the lamp will light up, but will remain dark on the good coils. A bell and battery may be used with the same results, the bell ringing on the defective coils only. The grounded coils should be carefully insulated with mica or good tape, and the leads soldered into position.

Bearings are sometimes allowed to wear so much that the armature rubs on the lower pole-pieces, wearing the banding wires to such an extent that they break. The bearings should be renewed, and the armature re-banded, and centered up with the pole bore. Be sure there is plenty of good insulation under the band wires, and if this insulation comes out, as is often the case in old machines, it should be renewed, and new banding wires put on the armature.

Commutator Troubles

Excessive sparking at the brushes is one of the troubles most frequently met with, and one or more of the following reasons may be assigned to its cause. In nearly every case this trouble is caused by the brushes being out of position, and care should be taken to see that they are properly spaced as mentioned above. If, after the brushes are properly spaced, sparking still occurs, look for high bars in the commutator, for if one or more of the commutator bars stand out above the others, there will be a flash every time the high bar passes under a brush. The best way to remedy this is to remove the armature from the machine and turn off the commutator smoothly in a lathe, using a sharp V-pointed tool.

A high mica segment will also cause sparking, and should be brought down with a file. If the commutator is not too rough it can

easily be smoothed with sand-paper, pressing this evenly against the surface while in motion. Better results are gained by raising the brushes from the commutator while sanding it off, and this can easily be done when the machine is running as a generator, but will not be so convenient in the case of a motor, unless some other source of power is available to rotate the armature. Never use emery paper for this work, as the dust may get between the windings of the armature and cause short circuits.

Sparking often results from excessive vibration of the machine, due to poor foundations, or to the armature itself being out of balance. If this is found to be the trouble, proper steps should be taken to remedy it. A weak motor field will often cause severe sparking, and the field connections should be made secure. Test the coils for short circuits and grounds as shown in Fig. 2. When a weak field exists in a motor, it will always be noticed that the machine takes a great deal more starting current than when operating under normal conditions. Sometimes the brushes are not of the proper material; if so, they should be exchanged for others, softer carbon being used for lower voltages—110 volts, for example—and harder carbon for higher voltages—500 volts, for example. It has often been found that a change of brushes has entirely stopped excessive sparking when all other means had been resorted to and failed.

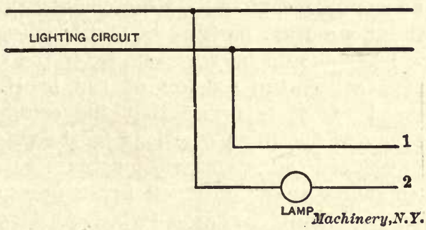


Fig. 2. Diagram of Wiring for Testing Armature Coils

The brushes should have just enough pressure on the commutator to make good electrical contact; if the tension of the brush-holder springs is too weak, sparking will occur, as the brushes cannot follow the inequalities of the commutator, especially when it is a little rough. Too much pressure should not be given to the brushes, as this will cause the commutator to heat more or less, and will wear the brushes and commutator away a great deal faster than necessary. Oftentimes it is found that the brushes do not cover the proper number of commutator bars, and some of different thickness should be tried. If the brushes in use are too thin, they can be made to cover more bars by beveling them at a greater angle, by tilting the brush ahead and re-fitting it to the commutator.

When sparking occurs at only one or two points on the commutator, the trouble is usually due to a short-circuited or grounded coil, and a test should be made for this as shown in Fig. 2. When the defective coil is located, it should be securely insulated with mica or other suit-

able material. If the sparking is allowed to continue for any length of time, it may result in "pitting" the commutator so badly that it will be necessary to turn it off in a lathe before being fit for service again.

It is often found that several commutator bars become blackened after the machine has been in service for some time, the cause arising either from grounded or partially short-circuited armature coils, defective mica rings or segments, or from cross-currents in the armature, set up by the brushes not being properly spaced. Directions have already been given for the repair of these troubles. Sudden or extreme fluctuations in voltage or sudden over-load will often cause severe flashing at the brushes. As this is due entirely to operating conditions, nothing further can be said than to eliminate these conditions as much as possible.

Troubles in the machine itself which cause flashing are poor brush contact on the commutator and wrong connections of the field windings in compound-wound machines. If the series field is connected in reverse to the shunt winding, flashing at the brushes is often the result. The series leads should be reversed, or if the trouble is due to the first-mentioned cause, the tension of the brush holder springs should be increased. If it is found that the commutator heats up above normal, it may be due to an over-load on the machine. If so, the load should be reduced or a larger machine substituted. Poor brushes, rough commutator or too much brush pressure always cause excessive heating, and should be cared for.

Never allow grease or dirt to accumulate on the brushes or commutator, and be sure that the brushes are having a good contact, and are pressing evenly against the commutator surface, fitting it perfectly at every point. After running a few days, the commutator should acquire a brownish glaze on the surface and nothing further need be done except to keep it clean by wiping it with a clean cloth every day or so. Very little lubrication is necessary, and none at all is a great deal better than too much.

The prime requisite for the successful operation of electrical machinery is cleanliness, and as stated in the beginning of the chapter, if the machine is kept cool, dry and clean, a great many of the troubles enumerated above will be greatly reduced, if not entirely eliminated.

CHAPTER II

DYNAMO AND MOTOR TROUBLES*

A number of small volumes have been written on the care of electrical machinery, particularly dynamos and motors. Most of these books are very useful in assisting the operator in the proper maintenance of the apparatus and the discovery of the causes of faults and breaks which are constantly liable to occur. Almost any given symptom of distress in a dynamo or motor, however, may be due to a number of different causes. This fact, together with the lack of method in the arrangement of some of the books dealing with the subject, often handicaps the beginner in locating the particular fault to which any given trouble is due.

Roughly speaking, the various diseases to which dynamos and motors are subject may be placed in six general classes, some of which have already been touched upon in the previous chapter. First, sparking of the brushes; second, heating of the parts; third, noises; fourth, variations in speed; fifth, miscellaneous derangements peculiar to motors as distinguished from dynamos; sixth, miscellaneous derangements peculiar to dynamos and generators as distinguished from motors. It is again possible to divide each of these major symptomatic indications into minor ones. The sparking of the brushes, for instance, may be due, first, to faults of the brushes; second, to faults of the commutator; third, to excessive currents in the armature; fourth, to faults in the armature. Each of these divisions may be again subdivided and an appropriate individual remedy indicated.

To make this clearer, the arrangement in the present chapter has been adopted for stating precisely, and in a limited space, the troubles met with and the remedies to apply. As an illustration we will suppose that the armature of a motor becomes dangerously hot after running for a time. The methodically arranged table or chart which follows is consulted and under the heading of "heating of parts" the sub-head "armature" is found. There are seven different causes given here for heating of the armature. It may be due to over-load of the motor, to a short circuit due to carbon dust, etc., on the commutator bars, or it may be caused by a broken circuit, a cross connection, moisture in the coils, eddy-currents in the core, or heat conveyed from a hot box or journals through the shaft. Each of these seven causes may be investigated in turn. For instance, it may be found that the armature core is warmer than the winding which surrounds it. If this is the case, the trouble is due to eddy-currents in the core, or to heat conducted through the shaft from a hot box. If the latter, the shaft will of course be hotter than the armature, and the bearings still hotter than the shaft. If the trouble is due to eddy-currents the armature

* MACHINERY, September, 1906.

will be found to be made of solid metal, or not to be sufficiently laminated. In either case the trouble is readily discovered.

There are two advantages in using a chart of this kind. In the case of trouble with a motor or dynamo, a large text-book is generally too voluminous to be easily used, and, quite likely, is not well enough arranged to permit a quick diagnosis. Then, again, after a person has carefully read over such a work several times, he will still find the chart very acceptable, as a guide which will show him where to look and what to do—something that can be glanced over quickly and can be readily found, which will outline the proper course to pursue. The trained mind will then quickly recall from the larger work the details of the proper method of procedure.

Sparking at the Brushes

FAULTS OF BRUSHES.

1. *Not set diametrically opposite.*—Should have been set properly at first, by counting bars, or by measurements on the commutator. Can be done if necessary while running; move rocker until brush on on-side sparks least; then adjust other rockers so they do not spark.
2. *Not set at neutral points.*—Move rocker back and forth slowly until sparking stops.
3. *Not properly trimmed.*—Brushes should be properly trimmed before starting by bending back and cutting off loose wires or ragged copper. If there are two or more brushes, one may be removed and retrimmed while running. Clean with benzine, soda or potash (alcohol or ether for carbon); then file or grind to standard jig and reset carefully. For instructions for setting see 1, 4, and 38.
4. *Not in line.*—Adjust each brush until bearing is on line and square on commutator bar, bearing evenly the whole width.
5. *Not in good contact.*—Clean commutator of oil and grit. See that brushes touch. Adjust tension screws and springs to secure light, firm, and even contact.

FAULTS OF COMMUTATOR.

6-7. *Rough; worn in grooves or ridges; out of round.*—Grind with fine sand paper on curved block, and polish with crocus cloth. Never use emery in any form. If too bad to grind down, turn off true in a lathe or preferably on its own bearings, with a light tool and rest and a light cut, running slowly. Armature should have 1/16 inch to 1/8 inch end motion when running, to wear commutator evenly and smoothly. See also that foundation is level. If there is no end motion, file or turn ends of boxes or shoulders on shaft to provide end motion; then line up shaft and belt, so that there is no end thrust on shaft, but so that the armature plays freely endways when running.

8. *High bars.*—Set "high bar" down carefully with mallet or block of wood, then clamp end nuts tightly, or file, grind, or turn true. A high bar may cause singing. If so apply stearic acid (ada-

mantine), candle, vaseline, or cylinder oil to commutator and wipe off; only a trace should be applied. Move brushes in and out of holder to get a firm, smooth, gentle pressure, free from hum or buzz.

9. *Low bars.*—Grind or turn commutator true to the surface of the low bars.

10. *Weak magnetic field.*—Broken circuit in field coils, or short circuit in field coils; repair if external, rewind if internal. Machine not properly wound or without proper amount of iron; no remedy but to rebuild it.

EXCESSIVE CURRENT IN ARMATURE OF GENERATOR.

11. *Excessive load.*—Reduce number of lamps and load.
 Ground and leak from short circuit on line.—Test out, locate, and repair.
 Dead short circuit on line.—Dead short circuit will or should blow safety fuse. Shut down; locate fault and repair before starting again, and put in a new fuse.

EXCESSIVE CURRENT IN ARMATURE OF MOTOR.

11A. *Excessive voltage.*—Use proper current only, and with proper rheostat and controller, and switch.
 Excessive amperes on constant current circuit.—See that controller, etc., are suitable with ample resistance.
 Friction.—Reduce load on motor to its rated capacity or less. Clean with benzine. Bearings may be loose or worn out; perhaps new bearings are needed. For bearings out of line, see 30.
 Too great load on pulley.—See that there is no undue friction or mechanical resistance anywhere.

ARMATURE FAULTS.

12. *Short circuited coils.*—(*a*). Remove copper dust, solder, or other metallic contact between commutator bars. (*b*). See that clamping rings are perfectly free, and insulated from commutator bars, and that there is no copper dust, carbonized oil, etc., to cause an electrical leak. (*c*). Test for cross connection or short circuit, and if such is found rewind armature to correct. (*d*). See that brush holders are perfectly insulated, with no copper dust, carbon dust, oil or dust, to cause an electrical leak.

13. *Broken coils.*—(*a*). Bridge the break temporarily by staggering the brushes until machine can be shut down (to save bad sparking) and then repair. (*b*). Shut down machine if possible, and repair loose or broken connection to commutator bar. (*c*). If coil is broken inside, rewinding is the only sure remedy. May be temporarily repaired by connecting to next coil, across mica. (*d*). Solder commutator lugs together, or put in a "jumper," and cut out, and leave open the broken coil. Be careful not to short circuit a good coil in doing this.

14. *Cross connections.*—Cross connections may have same effect as short circuit; treat as such, see 12. Each coil should test complete, with no cross and no ground.

Heating of Parts

ARMATURE.

15. *Overloaded.*—Too many amperes, lights, or too much power being taken from machine. See 11A.
16. *Short circuit.*—Generally dirt, etc., at commutator bars. See 12.
17. *Broken circuit.*—Often caused by a loose or broken band. See 12, 13, and 14.
18. *Cross connection.*—Often caused by a loose coil abrading on another coil or core. See 12 and 14.
19. *Moisture in coils.*—Dry out by gentle heat; may be done by sending a small current through, or causing machine to generate a small current itself, by running slowly.
20. *Eddy currents in core.*—Iron of armature hotter than coils after a run: faulty construction. Core should be made of finely laminated insulated sheets. No remedy but to rebuild.
21. *Friction.*—Hot boxes or journals may effect armature. See 25 and 33.

FIELD COILS.

22. *Excessive current.*—When shunt wound decrease voltage at terminals by reducing speed; increase field resistance by winding on more wire, finer wire, or putting resistance in series with fields. When series wound, decrease current through fields by shunt, removing some of the field winding, or rewind with coarser wire. Excessive current may be caused by a short circuit, or by moisture in coils, producing a leakage. See 24.
23. *Eddy currents.*—Pole pieces hotter than coils after short run, due to faulty construction, or fluctuating current; if latter, regulate, and steady current.
24. *Moisture in coils.*—Coils not dry show less than normal resistance; may cause short circuit or body contact to iron of dynamo. Dry out as in 19.

BEARINGS.

25. *Not suffiicient or poor oil.*—See that plenty of good mineral oil, filtered clean, and free from grit, is fed to bearings; be careful that it does not get on commutator or brush holder. See 12. Cylinder oil or vaseline may be used if necessary to complete run, mixed with sulphur or white lead, or hydrate of potash. Then clean up and put in good order.
26. *Dirt or grit in bearings.*—(*a*). Wash out grit with oil while running, then clean up and put in order. Be careful about not flooding commutator and brush holder. (*b*). Remove caps and clean and polish journals and bearings perfectly, then replace. See that all parts are free and lubricate well. (*c*). When shut down, if hot, remove bearings and let them cool naturally; then clean, scrape and polish, assemble, seeing that all parts are free, and lubricate well.
27. *Rough journals or bearings.*—Smooth and polish in a lathe, removing all burrs, scratches, tool marks, etc., and rebabbitt old boxes or fit new ones.

28-29. *Journals too tight in bearings; bent shaft.*—Slacken cap bolts; put in liners and re-tighten till run is over; then scrape, ream, etc., as may be needed, bend or turn true in lathe or grind true. Possibly a new box or shaft will be needed.

30. *Bearings out of line.*—Loosen bearing bolts, line up and block until armature is in center of pole pieces, ream out dowel and bolt holes and secure in new position.

31. *End pressure of pulley hub or shaft collars.*—See that foundation is level and armature has free end motion. If there is no end motion, file or turn ends of boxes or shoulders on shaft to provide end motion. Then line up shaft and belt, so that there is no end thrust on shaft, but so that the armature plays freely endways when running.

32. *Belt too tight.*—(*a*). Reduce load so that belt may be loosened and yet not slip. Avoid vertical belts if possible. (*b*). Choose larger pulleys, wider and longer belts with slack side on top. Vibrating and flapping belts cause winking lamps.

33. *Armature out of center of pole pieces.*—(*a*). Bearings throwing armature out of center may be worn out and need replacing. (*b*). To repair, however, center armature in polar space, and adjust bearings. Loosen bearing bolts, line up and block until armature is in center of pole pieces, ream out dowel and bolt holes and secure in new position. (*c*). File out polar space to give equal space all around. (*d*). Spring pole away from armature and secure in place; this may be difficult or impossible in large machines.

Noises

34. *Armature or pulley out of balance.*—Faulty construction; armature and pulley should have been balanced when made. May be helped by balancing on knife edges.

35. *Armature strikes or rubs pole pieces.*—(*a*). Bend or press down any projecting wires, and secure with tie bands. (*b*). File out pole pieces where armature strikes. See also 30 and 33.

36. *Collars or shoulders on shaft strike or rub box.*—Bearings may be loose or worn out. Perhaps new bearings are needed. See also 30 and 31.

37. *Loose bolt connection or screws.*—See that all bolts and screws are tight, and examine daily to keep them so.

38. *Brushes sing or hiss.*—(*a*). Apply stearic acid (adamantine), candle, vaseline, or cylinder oil to commutator and wipe off; only a trace should be applied. (*b*). Move brushes in and out of holder to get a firm, smooth, gentle pressure, free from hum or buzz. See also 3, 8, and 9.

39. *Flapping of belt.*—Use an endless belt if possible; if a laced belt must be used, have square ends neatly laced.

40. *Slipping of belt from overload.*—Tighten belt or reduce load. See 32.

41. *Humming of armature lugs or teeth.*—(*a*). Slope end of pole piece so that armature does not pass edges all at once. (*b*). Decrease magnetism of field, or increase magnetic capacity of tooth.

Variations in Speed

RUNS TOO FAST.

42. *Engine fails to regulate with varying load.*—Adjust governor of engine to regulate properly, from no load to full load.
43. *Series motor; too much current; runs away.*—Series motor on constant current: (*a*). Put in a shunt and regulate to proper current. (*b*). Use regulator or governor to control magnetism of field for varying load. Series motor on constant potential: (*a*). Insert resistance and reduce current. (*b*). Use a proper regulator or controlling switch. (*c*). Change to automatic speed regulating motor.
44. *Shunt motor: regulator not properly set.*—Adjust regulator to control motor.

    Shunt motor: not proper current.—Use current of proper voltage and no other, with a proper rheostat.

    Shunt motor: motor not properly proportioned.—Install better motor, one properly designed for the work.

RUNS TOO SLOW.

45. *Engine fails to regulate.*—Adjust governor of engine to regulate properly, from no load to full load.
46. *Overload.*—Reduce number of lamps and load.
47. *Short circuit in armature.*—(*a*). Remove copper dust, solder or other metallic contact between commutator bars. (*b*). See that clamping rings are perfectly free, and insulated from commutator bars, and that there is no copper dust, carbonized oil, etc., to cause an electrical leak. (*c*). Test for cross connection or short circuit, and if such is found, rewind armature to correct. (*d*). See that brush holders are perfectly insulated, with no copper dust, carbon dust, oil or dust, to cause an electrical leak.
48. *Striking or rubbing of armature.*—(*a*). Bend or press down any projecting wires, and secure with tie bands. (*b*). File out pole pieces where armature strikes. See also 30 and 33.
49. *Friction.*—Clean with benzine. See also 25.
50. *Weak magnetic field.*—Broken circuit in field coils or short circuit in field coils: repair if external, rewind if internal. Machine not properly wound, or without proper amount of iron: no remedy but to rebuild it.

Motor

STOPS OR FAILS TO START.

51-52. *Great overload; excessive friction.*—Open switch, find and repair trouble. Keep switch open and rheostat "off" to see if everything is in good order. With series motor no great harm will result from failing to start or stop. With shunt motor on constant potential circuit, fuse may blow or armature burn out. Reduce load on motor to its rated capacity or less. See that there is no undue friction or mechanical resistance anywhere. See also 25, 33, and 35.

53. *Circuit open: fuse melted or switch open.*—Find trouble. Put in fuse after opening switch. (If fuse is blown out on account of

dead short circuit, shut down, and locate and repair fault before starting again.)

Circuit open: broken wire or connection.—Open switch, find and repair trouble as instructed under 13.

Circuit open: brushes not in contact.—Open switch and adjust as stated under 5.

Circuit open: current fails or is shut off.—Open switch; return starting box lever to off position; wait for current.

54-55-56. *Short circuit of field, armature, or switch.*—Test for, and repair if possible. Examine insulation of binding posts and brush holders. Poor insulation, dirt, oil, and copper or carbon dust often result in a short circuit.

RUNS BACKWARDS.

57. *Wrong connections.*—Connect up correctly per diagram; if no diagram is at hand, reverse connections to brushes, or other connections, until direction of rotation is satisfactory.

Dynamo or Generator

REVERSED RESIDUAL MAGNETISM.

58. *Reversed current through field coils.*—Use current from another machine or a battery through field in proper direction to correct fault. Test polarity with a compass.

Reversed connections.—If connections or windings are not known, try one way and test; if not correct, reverse connections, try again and test.

Earth's magnetism.—Connect up per diagram for desired rotation; see that connections to shunt and series coils are properly made.

Proximity of another dynamo.—Shift brushes until they operate better. See 1 and 2.

Brushes not in right position.—See 1 and 2.

TOO WEAK RESIDUAL MAGNETISM AND SHORT CIRCUIT.

59. *Too weak residual magnetism.*—Use current from another machine or a battery through field in proper direction to correct fault. Test polarity with a compass.

60. *Short circuit in machine.*—(*a*). Remove copper dust, solder, or other metallic contact between commutator bars. (*b*). See that clamping rings are perfectly free, and insulated from commutator bars, and that there is no copper dust, carbonized oil, etc., to cause an electrical leak. (*c*). Test for cross connection or short circuit, and if such is found rewind armature to correct. (*d*). See that brush holders are perfectly insulated, with no copper dust, carbon dust, oil or dust, to cause an electrical leak. See also 54-56.

61. *Short circuit in external circuit.*—A lamp socket, etc., may be short-circuited or grounded, and prevent building up shunt or compound machines. Find and remedy before closing switch. See also 54-56.

62. *Field coils opposed to each other.*—Reverse connections of one of field coils and test. Find polarity with compass; if necessary,

use current from another machine or a battery through field in proper direction to correct fault. Test polarity with a compass. Connect up per diagram for desired rotation, and see that connections to shunt and series coils are properly made. Try shifting brushes until they operate better. If necessary reverse connections and recharge in opposite directions.

OPEN CIRCUIT.

63. *Broken wire.*—Search out and repair as stated in 13.
Faulty connections.—Search out and repair as stated in 37.
Brushes not in contact.—Search out and repair as stated in 5.
Safety fuses melted or broken.—Search out and repair as stated in 53.
External circuit open.—Search out and repair with dynamo switch open until repairs are completed.

EXCESSIVE LOAD OR RESISTANCE.

64. *Too great load on dynamo.*—(*a*). Reduce load to pilot lamp on shunt and incandescent machines; after voltage is obtained close switches in succession slowly, and regulate voltage. (*b*). Reduce number of lamps and load. (*c*). Bring up to voltage gradually with rheostat, and watch pilot lamp, regulating carefully.

65. *Too great resistance in field rheostat.*—Bring up to voltage gradually with rheostat, and watch pilot lamp; regulate carefully.

CHAPTER III

REPAIRS TO THE COMMUTATOR*

The most economical method of repairing electrical machinery in a manufacturing establishment, or electric railway plant, is a subject that should command the attention of the superintendent and electrician. The exorbitant charges of electrical repair concerns and the unnecessary delay in transportation of apparatus make it a practical necessity for companies of any magnitude to do their own repairing. In the present chapter a few suggestions are given for re-filling commutators. As the commutator is the part of a direct-current machine that is subjected to the greatest wear, its re-filling constitutes a large portion of the repairman's work.

It is always advisable, when possible, to purchase hard-drawn copper strips, drawn to gage, and cut them to required lengths. Old commutators are frequently so far out of date that standard sizes of segments will not do. A very good commutator can be made from a copper casting, similar in shape to the assembled commutator, that is, cylindrical in form and enough larger than the original commutator to allow for finishing. (See Fig. 3.) Large castings may be cored out at ends *a* and *a'*, for collars, thus saving some stock and considerable labor,

---

* MACHINERY, December, 1904.

as it is then only necessary to make a finishing cut after segments are assembled. Bore out the rough casting and drive it on an arbor and place on "centers" in a milling machine. Use a 1/16-inch saw about four or five inches in diameter. Cut as many slots in the casting as there are to be segments, *b*, Fig. 4. By using an indexing head this is a

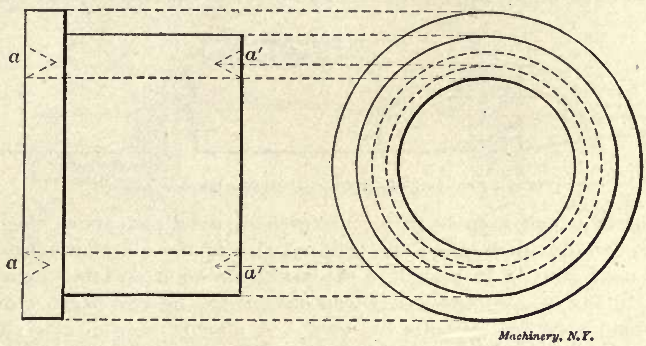


Fig. 3. Copper Casting for Commutator

very simple process. Cut the slots through to within 1/8 inch of the edge, as shown at *c*. The slots *a* for armature leads should be cut in after the commutator is assembled and turned. Now, drive out arbor and catch casting in a vise and finish cutting through the slots with a hack-saw. Two blades put in the frame at the same time will make a

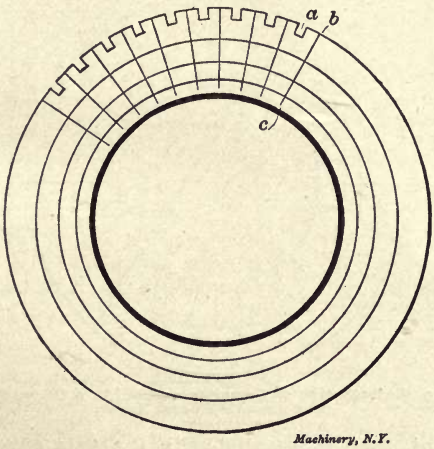


Fig. 4. Slots Cut in Casting for Commutator for Sawing apart Segments, and for Lead Wires

cut about equal in width to that made by the saw in the milling machine. File off any burrs that remain on segments and drill a hole in each one on flanged portion *a*, Fig. 5, in diameter about twice the width of slot cut for lead wires, and a little deeper. This hole aids greatly in soldering in armature leads, as the solder flows at once to the bottom

of slot. The insulation between the segments should be micanite about 1/32 inch in thickness. As the segments are sawed up by a 1/16-inch saw, the rough casting must be made large enough to allow for the difference. For instance, in sawing up a casting into 32 segments, two inches of the circumference would be wasted. Using 1/32 inch micanite would make up for one inch only, so that the rough casting

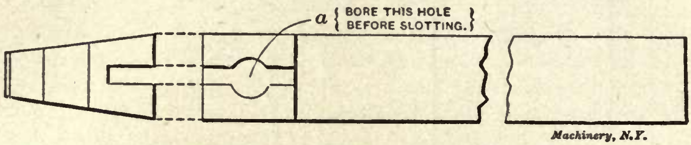


Fig. 5. Segment of Commutator after Sawing apart

must be one inch greater in circumference—over and above the stock allowed for finishing—than the original size of the old commutator.

The next step is to assemble the segments in a suitable clamp, as shown in Fig. 6. This is a cast-iron split ring, the two parts, *c* and *c'*, being held together by bolts *d* and *d'*. A plan of section *c* is shown; *a* and *a'* are dowel pins, and *b* and *b'* are clearance holes for bolts *d* and *d'*. Great care must be taken in assembling the segments to have

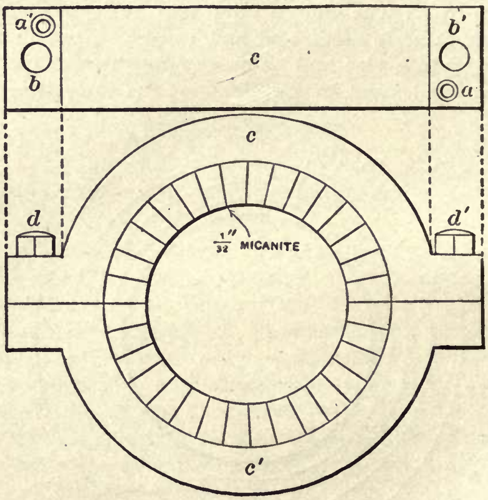


Fig. 6. Segments of Commutator Held in a Clamp for Machining Hole and Ends

them all straight, that is, parallel with the axis of the commutator. Now, chuck the clamp, with the segments, in the lathe, and bore out the center to required diameter, then bore out the ends to correspond with the old commutator. A templet of tin made to fit the end bore of the old commutator is very convenient for gaging the new one.

It is more economical to make several commutators at one time, so that a temporary shaft, with collars and clamping nuts, should be

provided. Such an arrangement is shown in Fig. 7, *d* being a short length of cold-rolled steel threaded at *e* and *e'*; *a* and *a'* collars bored out to slip over shaft, and *b* and *b'* clamping nuts. The temporary shaft should be firmly secured to the newly-bored segments before removing the clamping ring. This done, the ring may be removed

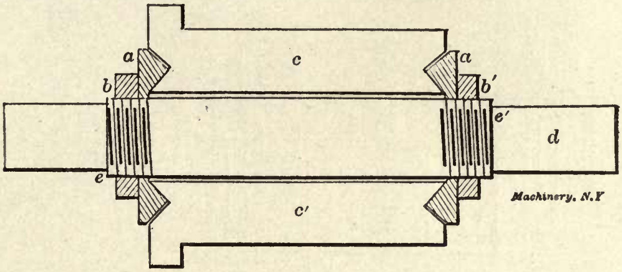


Fig. 7. Arbor for Holding Segments while Turning

and the new commutator will be ready for turning, as shown in section at *c* and *c'*, Fig. 7. Before turning, the commutator should be heated until the shellac oozes from the micanite, then placed on end on a surface-plate with a hole for shaft to extend through. This plate is shown at *d*, Fig. 8.

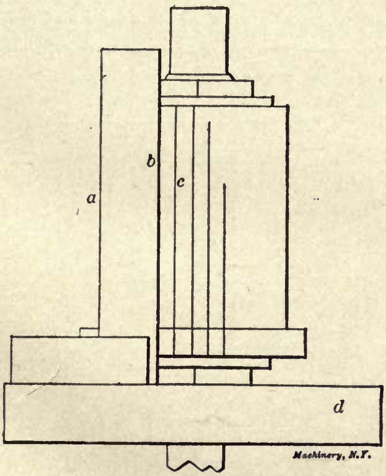


Fig. 8. Testing Alignment of Segments

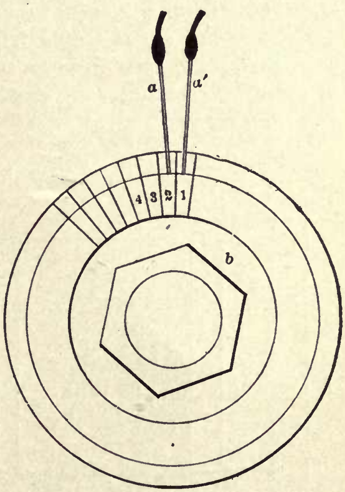


Fig. 9. Testing the Commutator for Short Circuit

Place a try-square on the plate and sight along the blade to see that the edge of one of the segments coincides with it, as at *b* or *c*. If not, by using a small cold-chisel and hammer, drive the segment one way or the other until plumb. Go all around the commutator in this manner. After straightening all the segments, tighten up the clamping nuts again and allow the shellac to dry. After the finishing cut is

taken, the commutator should be returned to the milling machine and the slots cut for lead wires, as shown at *a*, Fig. 4. When all burrs have been removed, we are ready to put on the retaining band, which firmly holds the segments in place until used.

Fig. 10 shows a method of putting on the band. The segments, *a*, are placed between lathe centers, and a heavy piece of manila paper is

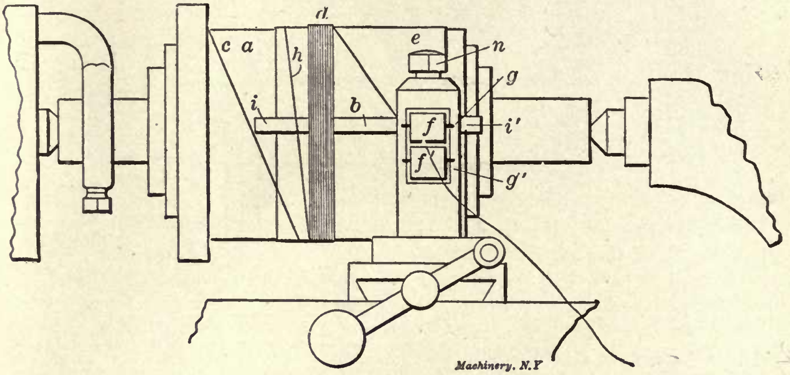


Fig. 10. Method of Putting on Retaining Band

wrapped around them, as shown at *e*. This is held in place temporarily by a cord, which also serves to hold in place a piece of 1/32-inch brass, *b*. Now cut two fiber friction blocks, *f* and *f'*, to fit in the tool-post, bore a hole and insert a pin in each, *g* and *g'*, to keep the blocks in place. Any amount of tension can be placed on the blocks by the clamping screw *n*.

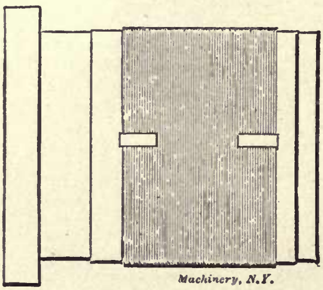


Fig. 11. Commutator with Retaining Band in Place

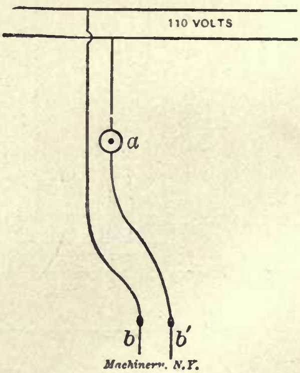


Fig. 12. Arrangement for Testing the Commutator

Take the end of a coil of No. 16 brass wire, and pass it between friction blocks, *f* and *f'*, and catch it in one of the slots, as at *c*. Turn the assembled segments two or three revolutions until the wire is brought over the paper *e*, then cover about one-half the length of the segments closely and very tight. When the desired amount of wire has been wound on, turn the ends *i* and *i'* of the brass strip *b* over on

wire, and hammer down, bringing the turn *h* close up to the band. Flow solder over the band with an iron and cut off the ends of wire. The commutator may then be removed from the temporary clamping device, when it will have the appearance shown in Fig. 11. The temporary clamping device, the clamping ring, and templets, can be used indefinitely. One clamping ring can be used for several sizes of commutators by using split bushings.

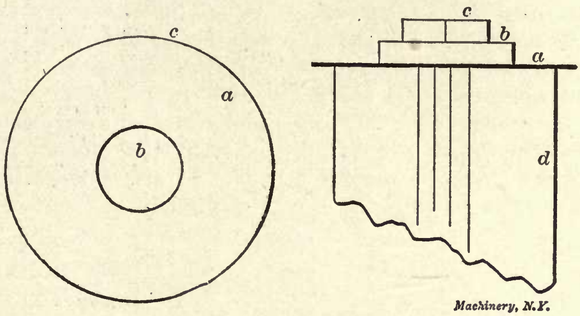


Fig. 13

When removing old segments from a commutator, care should be taken to keep the molded mica insulation on the ends intact. If this is broken it can be replaced by canvas disks, shown to the left in Fig. 13, made up of several pieces shellaced together to obtain a thickness equal to the molded mica. Place the old commutator sleeve, with the rear collar attached, end down on a bench and slip the canvas disk over sleeve to bottom. A hole in the disk should fit tightly over the sleeve, and the outside diameter should be about one inch greater than that of

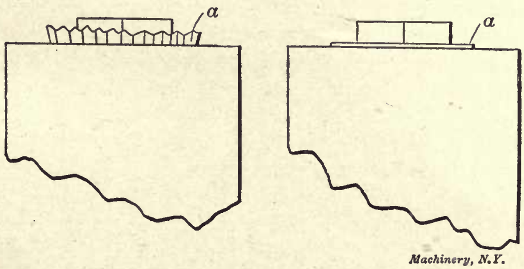


Fig. 14

the commutator. A sheet of flexible micanite must be wrapped around the commutator sleeve, to insulate it from the inside of segments. After placing the assembled segments *d*, over the sleeve, slip on the upper canvas disk *a*, as shown to the right in Fig. 13, then collar *b*, finally tightening up nut *c*. Canvas disks should be put in with shellac, wet. After screwing up the nut firmly, allow all dampness to dry out thoroughly. The canvas disks will then protrude between collars and segments as shown at *a*, to the left in Fig. 14. Trim off smoothly, giving a finished appearance as at *a* to the right in Fig. 14.

The completed commutator is now ready for testing. A very convenient and fairly accurate method is shown diagrammatically in Fig. 12. A sixteen candle-power incandescent lamp is connected in series with the mains, and two flexible cords with solid copper tips, *b* and *b'*. Fig. 9 shows the application of the testing arrangement. The copper tips, *a* and *a'*, are placed on adjoining segments, as at 1 and 2. If there is a short circuit, the lamp will light. Test each segment in turn in this manner. Then, by placing one of the tips on the end of the collar, as at *b*, and touching the other to each segment in turn, any leakage from segments to core will be found. If no leak is found the commutator is ready for use. If a leak or short-circuit appears, the trouble must be located and remedied before using.

Small copper chips wedged in the micanite by the turning-tool often cause a short circuit between segments. A careful inspection inside and outside after turning will generally disclose any such defect.

CHAPTER IV

REPAIRS TO THE ARMATURE WINDING*

The repair shop of a manufacturing plant or electric railway plant should have at hand suitable stands or "horses" for holding armatures during the winding process. If the armature is small, short stands may be mounted on a work-bench. When an armature comes in to be repaired, carefully caliper its diameter outside of the bands and the winding. Observe particularly the shape of the ends. As the workman proceeds to tear apart the armature, he should note the size of wire, style of winding, number of coils, convolutions per coil, number of layers, and all other details. All such data should be recorded, as this information will be of future value. It is well to head the record with the name of the machine, horsepower, voltage and current, speed and serial number of the armature.

The first step in unwinding an armature is to unsolder the leads and remove the commutator. Then cut off the bands and remove the wire. If the coils are of the formed type, laid in slots, raise the upper half around the entire circumference, and remove the coils, in the reverse order to that in which they were put in. After the core is entirely stripped of winding and insulation, it is ready to re-insulate.

Fig. 15 is a sectional view of a smooth-core drum armature insulated ready for winding. In the figure, *a* is the core; *b* and *b'* the ends of shaft covered as shown; c^1, c^2, c^3, and c^4 are fiber pegs for separating the coils; *d* and *d'* insulation on core, and *e* and *e'* insulating end disks. Fig. 16 shows the manner of notching the core-insulation to fit between the fiber pegs. Flexible micanite 1/32 inch in thickness,

* MACHINERY, January, 1905.

and held in place temporarily by a few turns of "flax," forms an excellent insulation. A ring armature, partially in section, is shown in Fig. 17. The shaft, *a*, pressed into the hub, *d*, carries the spider, to which is attached the ring *b*. One wing of the spider is shown at *c*. A flexible micanite insulation, *e*, covering the outside, inside and ends of ring, is held in place by a tight wrapping of cotton tape, as shown at *g*. The wings of the spider must be insulated. This can be done conveniently, as shown in Fig. 18, which shows a sectional end view of an armature, *a* being the armature ring, *b* the spider wing, and *c* and *c′* triangular-shaped pieces of micanite extending the length of the wing. The triangular pieces are retained in position by the wrapping of cotton tape.

A section of a slotted armature is shown in Fig. 19. Here *a* is the end in section; *b* and *b′* are slots not yet insulated; *c* is a hard-wood

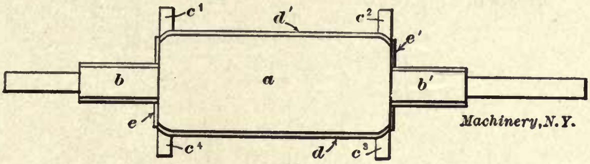


Fig. 15

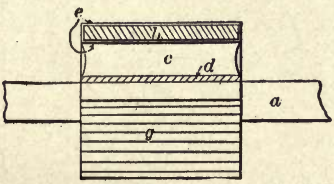


Fig. 17.

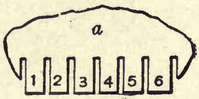
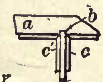


Fig. 16.



Machinery, N.Y.

Fig. 18.

Figs. 15 to 18

or fiber block the length of the slot and slightly narrower; *d* is micanite insulation driven in place by the block *c*; *e* is a slot insulated ready for the coil; *f* and *f′* are armature coils; *h* is the insulation between the coils; and *i* and *i′* the slot insulation trimmed flush with core *a*. The micanite is cut into strips of the required size, and folded over the block *c*, to form troughs, as shown. Another form of slot coming generally into use is shown in Fig. 20, in which *a* is the end of armature; *b* and *b′* V-shaped slots cut for receiving the wood retaining-strip *e*; *c* and *c′* coils in the slot, with insulation *d* between them.

Fig. 21 is an end view of an armature partially in section. This view illustrates the winding process with a form of coil in common use. In the figure, *a* is the shaft; *b* the end of the armature; *c*, a piece of sheet brass the length of the slot and about 4 inches wide; 1, 2, 3, 4, 5, 6, 7, and 8 show the coils with one-half free and one-half in slots; 9, 10, 11, 12, 13, 14, 15, and 16 show one-half of the coil in cross-section. Proceeding to wind an armature of the type shown in Fig. 21, the first process is to insulate the slots in the manner already described, then

drive one-half of the coil into place, continuing around the armature, thus filling half of each slot. The armature will then appear as shown. Fig. 22 is a piece of vulcanized fiber, shaped for driving coils into slots. In a four-pole machine each coil will have a pitch of 90 degrees, that is, it will cover one-fourth of the periphery of the armature. The coils slip into the slots easily, with the exception of those on the last quarter. Beginning at a point three-fourths of the distance around the armature from the first coil, the outer half of the coils that have been laid in, will lap over the empty slots. At this point a little more labor is involved in getting the coils into their respective places. Hav

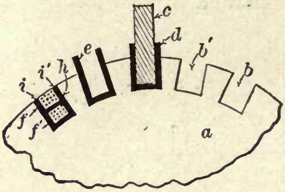


Fig. 19.

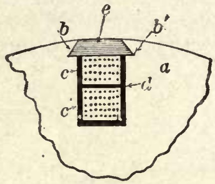


Fig. 20.

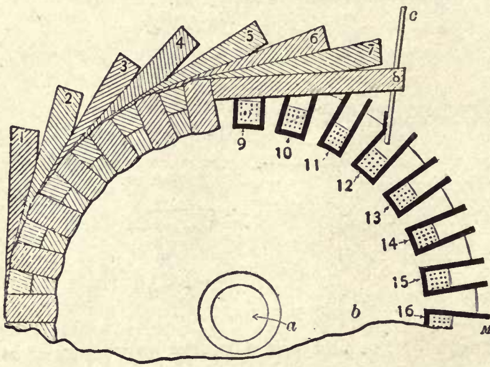


Fig. 21.

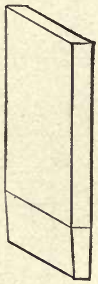


Fig 22.

Machinery, N.Y.

Figs. 19 to 22

ing completed the first process, start at any point to drive the outer half of the coils into slots. Hold the piece of brass, *c*, before referred to, in the left hand and slip it into the position shown. In this way it guides the coil 8 into the slot. With a mallet and the tool shown in Fig. 22, drive the coil snugly into place. Continue with each coil in like manner until all have been driven into their proper positions.

In Fig. 23, the periphery of the armature is supposed to be laid out flat. In the figure, *a*, *b*, and *c* are coils of the oblong type, which form a chordal winding. It will be seen that the coils are staggered, that is, the projecting ends alternate backward and forward. With this style of winding, the ends of the armature core must be well insulated. The coils, if not pounded into shape with a mallet, will interfere at *d*, *e*, *f*, *g*, *h*, *i*, *j*, and *k*. The coil *a* extends from slots 1

to 6; *b* from 2 to 7, and *c* from 3 to 8. No specific directions can be given here for shaping these coils, as no two makes of armatures are alike. By noting carefully the shape of the original coil, it will be an easy matter to form the new one. The winding is executed in a manner similar to the formed-coil winding previously described.

Taking up the subject of smooth-core drum armatures, let us study Figs. 24 to 29 inclusive, which illustrate some common types of winding. Starting with Fig. 24, we will assume each coil, for the sake of simplicity, to be one layer deep and three convolutions in width. Stand facing the commutator end of the armature, and tie the end of wire *a* to the fiber peg. Pass the wire downward over the end of the armature core and between the two pegs, diametrically opposite the starting point. Turn the armature over and draw the wire tight along its surface to the back end. Carry the wire around the shaft,

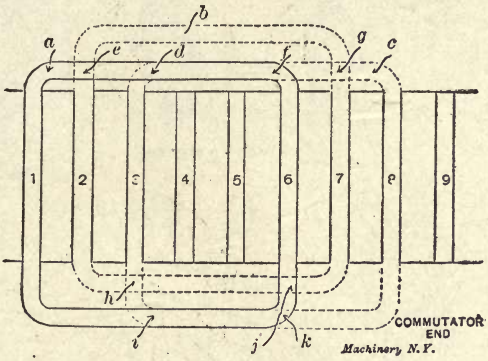


Fig. 23. Development of Surface of Armature

on the side opposite that followed on the front end, and through the pegs back to the starting point, having in the meantime turned the armature over to its original position. It is convenient to have the reel of wire suspended over the workman's head, so that the wire will pay off freely. Cut the wire from the reel, leaving end *b*. The ends must be long enough to be soldered into the commutator.

Now turn the armature over and begin the second coil to the right of the first one. This will bring the second coil to the left of the first one at the bottom side, as shown in Fig. 25. The ends *c* and *d* are left for connection to the commutator, as in the first instance. To commence the third coil, turn the armature over again and start at the right of the second coil, Fig. 26, twisting the end *e* around end *b*. Proceed in this manner until all the coils are wound. Fig. 27 gives an idea of the appearance of the armature end after three coils have been wound. It will be seen that every second space between the pegs has two ends. The inner end of the first coil is connected to the outer end of the third coil, there being a blank coil between the two, thus forming a closed or re-entrant winding. Any number of layers or convolutions may be used in this winding. Fig. 28 shows a similar winding, that can be used for two layers, or a multiple of two. The

only difference is that the second coil is commenced at the ending of the third, and so on until every space is filled, as shown in Fig. 29. If the winding when completed is to be four layers deep, the coils from 1 to 15 inclusive will have two layers, and the remaining coils to be wound will also have the same number. The half *A* of the armature will have no ends at this stage of the winding. The second set of coils, the ends of which protrude in *A*, commences at 15 and extends around to 1. The outer end of one coil joins to the inside of the next. This is clearly shown in Fig. 28, where end 3 of the second coil joins end 2 of the first coil, and so on. It is unnecessary to cut the wire as it can be left in loops as shown at 1, 2, 3, etc., in Fig. 29.

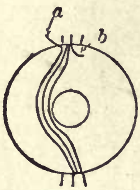


Fig. 24.

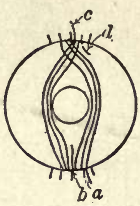


Fig. 25.

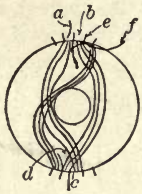


Fig. 26.

Fig. 27.

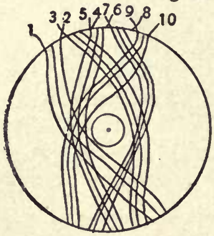


Fig. 28.

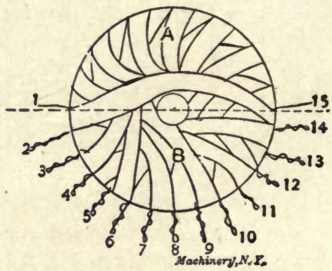


Fig. 29.

Figs. 24 to 29

We will now turn to smooth-core ring armatures. In Fig. 30, *a* is the shaft and *b* the spider hub, to which are attached the wings, c, c^1, c^2 and c^3, bearing the ring *d*. The winding forms a continuous spiral, the end 2 of coil 1 being attached to end 3 of coil 2, etc. As the space or the inner surface of the armature is less than that of the periphery, the winding will have a greater number of layers inside than on the outer surface. An exaggerated view of a method of winding to accomplish such a result is shown in Fig. 31. The wire starts at *a*, then passes around the ring and comes to the front at *b*, passes under at *c*, and returns at *d*. It is then carried under at *e*, between *a* and *c*, starting the second layer on the inner surface. From *f*, the wire goes to *g*, and back to *h*, thence to *i*, between *c* and *g*, coming back at *j*. Thus we have five convolutions and one layer on the outer surface, and two layers—one of three and one of two convolutions—on the inner surface.

In Fig. 32 the application of the clamp shown in Fig. 33 is given. This clamp consists of two wood pieces, *f* and *f′*, and two bolts, *g* and

g', with heads, *h* and *h'*, and thumb nuts, *i* and *i'*. This clamp serves to hold the wire of each coil in position while winding, and is moved around as fast as a coil is completed. Referring again to Fig. 32, the wood piece, *e*, is used for filling the gap in the outer surface of the winding caused by the spider wings, d, d^1, d^2, d^3. It is made equal in width to the wing, and of the same depth as the winding. In balancing an armature one or more of these strips may be removed and lead strips wound in tape substituted. All armatures must be carefully balanced, which can be accomplished by several methods, one of which has just been mentioned. If the air-gap of the machine has clearance enough, solder may be flowed onto the bands. With slotted armatures, some makers bore holes in the core on the heavier side, thus equaliz-

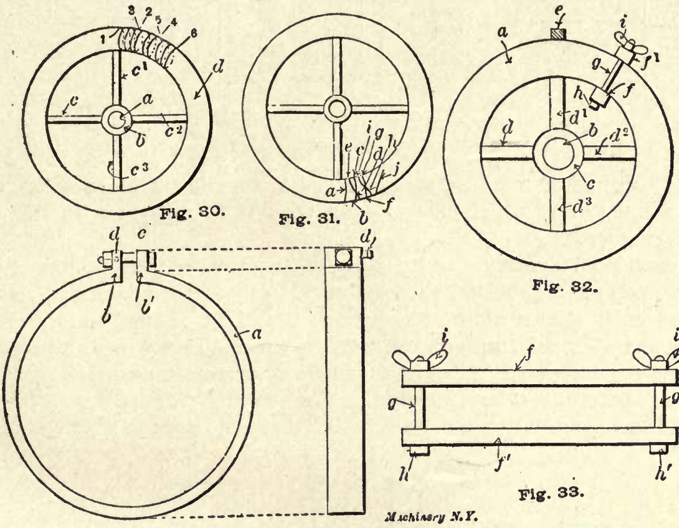


Fig. 30. Fig. 31. Fig. 32. Fig. 33. Fig. 34.

Figs. 30 to 34

ing the weight. Another method is to bind a piece of sheet lead on the front end of the armature over the lead wires, by a tape and cord.

As no definite rule can be given for soldering lead wires into a commutator, only a few suggestions will be offered. Tin the slots in the segments and the armature leads before soldering. See that the slot is flowed full of solder. Do not use acid for flux on small wire, as corrosion will take place. Be extremely careful that no drops of solder lodge between or back of the segments. Each coil should be tested for grounds as it is wound, and to make sure that the right ends are connected. A convenient testing arrangement was explained in the previous chapter on Repairs to the Commutator, and can be applied in this case also. A magneto bell, a galvanometer or a Wheatstone bridge may be used for testing purposes.

Fig. 34 gives two views of a clamp that is used in winding armature bands, *a* being a hoop of band-iron, with its inside diameter equal to

the outside diameter of the armature. The ends *b* and *b′* are bent up as shown, and bored to receive a clamping bolt, *c*. A pin, *d*, is attached to the end, *b*, for fastening the binding wire. Fig. 35 shows clearly the practical application of the clamp. In this sketch, *a* is the armature; *b*, the clamp; *c*, the pin; *d*, the band being wound; *e* and *f*, finished bands; *g*, mica insulation under bands; *h*, h^1, and h^2, brass clips for holding the bands together. The lathe centers are shown at *i* and *i′*. The end of the brass wire *j* passes through the fiber friction blocks in the toolpost.

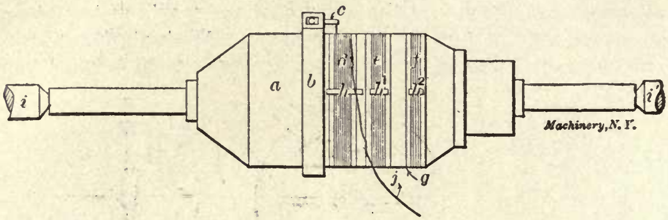


Fig. 35. Application of Clamp in Fig. 34

The manner of winding an armature is esentially the same as that of a commutator, which has already been fully described in the previous chapter.

A completed armature, with slots of the type shown in Fig. 20, is illustrated in Fig. 36. The core, with wood retaining-strips driven into slots, is shown at *a*. Mica strips *b* and *b′*, under bands *c c*, are for the usual insulating purpose. Brass chips *d* and *d′* are attached in the regular manner. Armatures with wood retaining-strips in slots require but two bands, which are wound on the coil ends that project beyond the core.

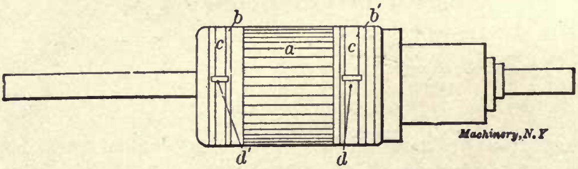
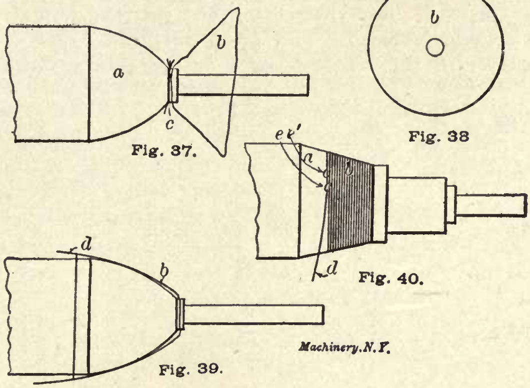


Fig. 36. A Completed Armature

A method of protecting the ends of a surface-wound drum armature is illustrated in Figs. 37, 38, 39, and 40. A canvas disk, *b*, Fig. 38, is tied by a cord, *c*, to the end of armature *a*, Fig. 37. The disk is then drawn over the end and tied temporarily with a cord, *d*, as in Fig. 39. The armature band serves to hold this hood in place permanently. An effective manner of finishing the commutator end of an armature is illustrated in Fig. 40. The end *a* is wound tightly with cord about ¼ inch in diameter, as shown at *b*. Two loops of string, *e* and *e′*, are caught under the last two or three turns of cord and the end *d* is pased through them, after which the loops are drawn up, the ends trimmed off and the cord cut close to the last loop. After the armature is completed, it should be given a thorough coating of shellac

and placed in an oven. When fully dried out, put on two even coats of P. & B. compound, which gives it a good black and waterproof finish.

As a complete description of the numerous styles of connecting up armatures is beyond the scope of this book, only a few of the common types will be taken up. For further information on this subject the



Figs. 37 to 40

reader is referred to one of the many text-books on dynamo-electric machinery.

Fig. 41 illustrates, graphically, a lap-winding. The poles of the machine are represented at *S*, *N*, *S*, *N*, and the commutator segments are indicated by the squares *a*, *b*, *c*, etc. We will take, for example, the coil starting at *b*. The conductor passes over the left face of the

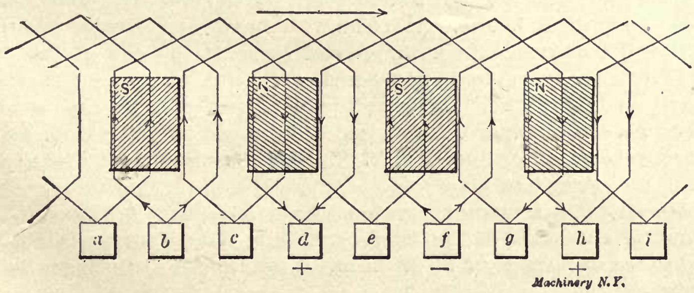


Fig. 41. Graphical Illustration of Lap-winding

S pole, and then returns over the middle of the *N* pole, to the adjoining segment, *c*. This series of loops is continued around the armature, forming a complete circuit. The large arrow indicates the direction in which the conductors are moving, and the small arrow-heads on the wires show the disposition of the current.

A diagram of a hand-wound armature, with a wave winding, is shown in Fig. 42. To avoid complications, nineteen coils only are shown.

This type of armature is extensively used by the Shaw Electric Crane Company. The small white circles around the circumference of the armature, as at *b*, represent the first layer of wire; the black circles, at *a*, show the outer layer. The dotted lines indicate the conductors passing over the back end of the armature. Starting at the commutator segment 1, the conductor goes to *b*, then to *c*, and connects to segment 10. Here we start a new coil, going to *d*, then to *e*, and connecting to segment 19, one space from the starting point. The third coil starts here and leads to *f*, and so on until one layer is completed, when one-quarter of the circumference of the armature on each side

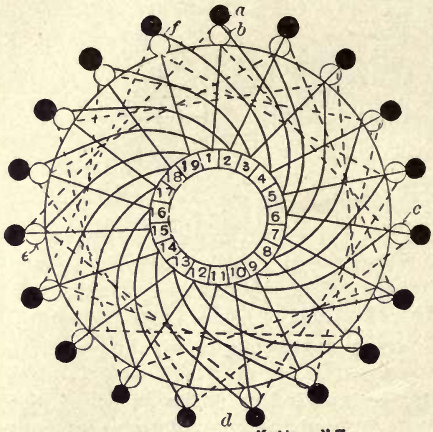


Fig. 42. Diagram of Hand-wound Armature

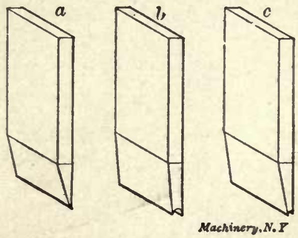


Fig. 43. Tools for Winding Armatures

will have ends protruding, that is, the first quarter will have leads, the second will be blank, the third will have leads again, and the fourth will be blank. Start the second layer at the end of the first one. When the winding is completed, each slot will have two ends, as shown in the figure. An armature with formed coils can be connected in a like manner. A few handy tools can be made from fiber; they are shown at *a*, *b*, and *c*, in Fig. 43. These tools are used for driving the wires into place, etc.

Rewinding an armature requires great care and neatness. The dimensions and shape of the original winding should always be closely followed, as an armature which is but a fraction of an inch too large is useless.

CHAPTER V

REPAIRS TO ARMATURE AND FIELD COILS*

An illustration of an armature coil of the most common type now in use, is given in Fig. 44. This coil requires somewhat more labor to prepare than does the rectangular form, but is much easier to use when rewinding armatures, as no portion of it passes over the end; and it has the further advantage of allowing better ventilation. Another type in use is the plain, rectangular form, shown in Fig. 49. Such a coil is easily made, but requires considerable manipulation after it is placed in the armature. The forms over which these two styles of coils are wound are similar in design but different in shape. Fig. 45 shows a form, in which *a* is a standard fastened to bench or

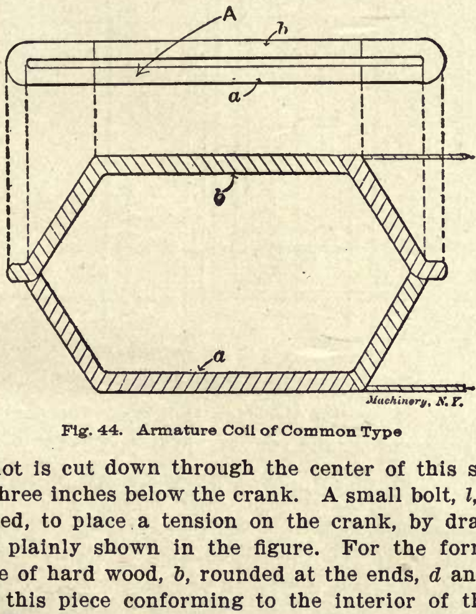


Fig. 44. Armature Coil of Common Type

floor, and a slot is cut down through the center of this standard to a point two or three inches below the crank. A small bolt, *l*, with thumb-nut, is provided, to place a tension on the crank, by drawing up the slot. This is plainly shown in the figure. For the form proper we require a piece of hard wood, *b*, rounded at the ends, *d* and *d'*, the size and shape of this piece conforming to the interior of the coil to be wound; and two side pieces of wood, *c* and *c'*, slightly larger in dimensions than the center piece, so that when placed on each side concentrically with the center, a spool is formed. The side *c* is fastened permanently to *b*, while *c'* is held in place by two thumb-nuts, *e* and *e'*, which allows the coil to be readily detached from the form. The flange *f* is attached to the short shaft with crank and handle *j*. The illustration shows elevation and side view. The notches, *g* and

* MACHINERY, February and June, 1905, and May, 1906.

g′, *h* and *h′*, *i* and *i′*, are for fastening the ends of the wire and for the retaining-strips, which will be explained later.

Fig. 46 gives plan and end views of the shaper for shaping coils of the style shown in Fig. 44, in which *g* is the wood base, *a* is the coil that has been shaped, *b* and *b′* the clamps; *c*, *d*, *e* and *f*, wooden strips, of the shape indicated. The pieces *d* and *e* are fastened to the base *g* by screws. The operation of this shaper will be taken up in its turn. Fig. 47 represents a reel of magnet wire, *a*, swung on a suitable support, *b*, and provided with a tension. The tension consists of a piece of hard brass wire, about No. 10 or 12, fastened to base *b* and passing around a groove in one side of the reel to a weight, *d*. With

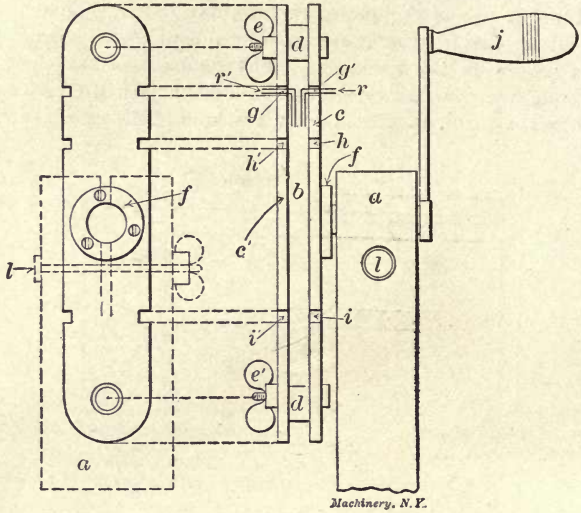


Fig. 45. Form for Winding Armature Coils

the wire *e* paying off in the direction indicated, the desired amount of tension may be placed on the reel by varying the size of the weight.

Fig. 48 represents a handle for guiding the wire onto the form. This handle should be made of fiber or hard wood. The end *c* is beveled off as shown. A hole or slot, *b*, extends through the handle, through which the wires pass. The handle is held in the left hand, while the form is rotated with the right hand by means of the crank already mentioned. Some styles of coils are wound with two or more wires laid on in parallel at one time. The reason for this is that in machines of considerable size, a single conductor of sufficient carrying capacity would be too stiff for handling. Under such conditions the handle should have a slot at *b* instead of a hole, and a separate reel for each conductor should be provided, one placed back of the other.

The materials used in armature coils are: Double, cotton-covered magnet wire, ½- or ¾-inch cotton tape, insulating tape, a good quality of orange shellac, and some strips of 1/32-inch sheet brass. The cotton tape can be procured at any department store in rolls of various sizes.

A drying oven is an essential part of an electrical repair shop, and when there is steam or gas in the building it is an easy matter to provide one. Its capacity must be determined by the size and quantity of the work to be done. An angle-iron frame, with 1/16-inch iron or steel lagging for siding and doors, makes an excellent oven. The doors should be on the front and extend from top to bottom. The interior of the oven must be provided at the lower portion with a suitable stand for holding armatures, and above the stand, metal racks, for drying coils and commutators. Steam coils or gas burners may be used for heating the oven. A good temperature for drying is about 200 degrees F. Too much care cannot be taken in following the dimensions of old coils, as a little variation will cause trouble when placing the new coils in an armature.

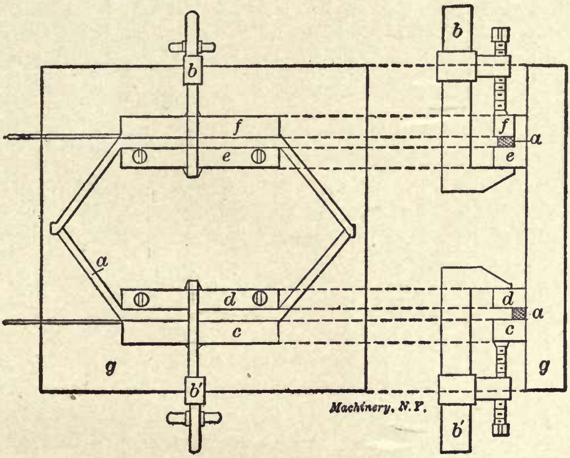


Fig. 46. Shaper for Coils shown in Fig. 44

In general, do not use metal for driving wires into place; use hard wood or fiber. If bare spots appear in the course of winding, insulate them at once. Do not cut the ends of the wire too short. It is easier to cut off a little more than to splice on. Tape the coils tightly and let the convolutions lap well, so that they will not pull apart when shaped. The lead wires, or ends of coils, should be carefully covered with insulating tape. Soldering in of lead wires is greatly facilitated by tinning the ends before driving them into the commutator slots. The beginner, undoubtedly, will have to make several attempts before completing a perfect coil. Neatness is of great importance, and every portion should be well done before proceeding further.

We will now wind and insulate a coil, and follow out each detail. Assume that a set of coils, similar to that shown in Fig. 44, is to be made. It is supposed that the winder has one of the old coils for inspection. With a wire-gage determine the size of wire, and note whether one or more wires are run in parallel for one conductor. This done, carefully unwind one turn and measure its length; this will be

the circumference of the form to wind the new coil on. A coil of this style should be wound on a long, narrow form, similar to that shown in Fig. 45. Some armatures have two coils per slot, that is, two coils made up as one, with their respective ends brought out separately. Consider that we are about to wind a double coil, with two wires in parallel for one conductor. This will necessitate winding on four wires at one time.

Arrange four reels of magnet wire, one back of the other, and push the four ends through the slot in one guide. Suppose the desired length of the armature leads, or coil ends, to be six inches. Now bend at right angles the two right-hand wires, about six inches from the ends passed through the guide, then bend the two left-hand wires in the opposite direction. This being done, slip the two pairs of bent ends into the slots *g* and *g′* in the manner shown at *r* and *r′*, Fig. 45. Say that the coil is four convolutions wide and three layers deep. Having secured the ends as described, turn the crank two and one-half

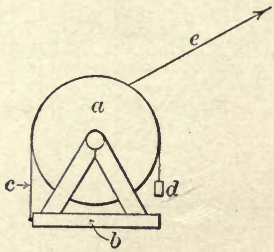


Fig. 47

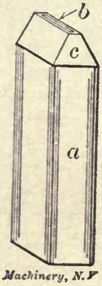


Fig. 48

times, bringing the outer ends of the coil through the slots on the opposite side to *g* and *g′*, using care to retain the ends in their original order. During the winding process the guide should be held firmly in the left hand, and the wires pulled down tightly into the form. Now cut off the wires from the reels, leaving six-inch ends on the coil, as at the beginning.

Cut four narrow strips of 1/32-inch brass, about 1 inch long, and slip one under the coil through the slots *h* and *h′*, *i* and *i′*, and also through the four corresponding slots on the opposite side of the form. Bend the strips up over the coil, and tap down lightly with a mallet, taking care not to break the insulation. Loosen the thumb-nuts, *e* and *e′*, slip off the side *c′*, and remove the coil. Make up the desired number of coils in this manner before insulating them. Having completed the winding, cover the four ends—that is, the eight wires—with good insulating tape. These leads should be covered from the point where they bend through slots in the form, to about one inch from the end. The next operation is to carefully wrap the whole coil with cotton tape, giving it the appearance shown in Fig. 44. The leads must be left protruding the distance covered with insulating tape.

We will now shape the coil, as in Fig. 46. The two halves of the coil, after being taped, should be pressed closer together, giving the

coil the appearance shown at *A*, Fig. 44. Insert one of the halves between the strips *c* and *d*, and clamp it tightly. With the protruding half grasped with both hands, pull it over the strip *e* and clamp as shown. With a small fiber mallet, pound the ends into symmetrical shape. Remove from shaper, and immerse in a suitable receptacle

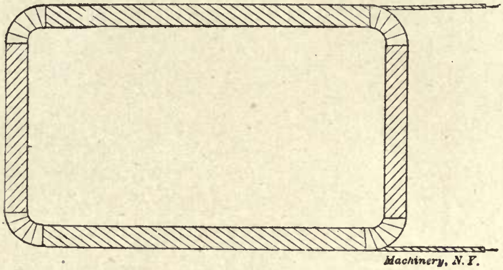


Fig. 49. Plain Rectangular Form of Armature Coil

filled with thin shellac. When thoroughly impregnated, allow superfluous shellac to drip off, and place in oven to bake. The rectangular coil shown in Fig. 49 can be made on a form similar to the one described, having its dimensions correspond to the shape of the coil. A little practice will render the workman proficient, and enable him

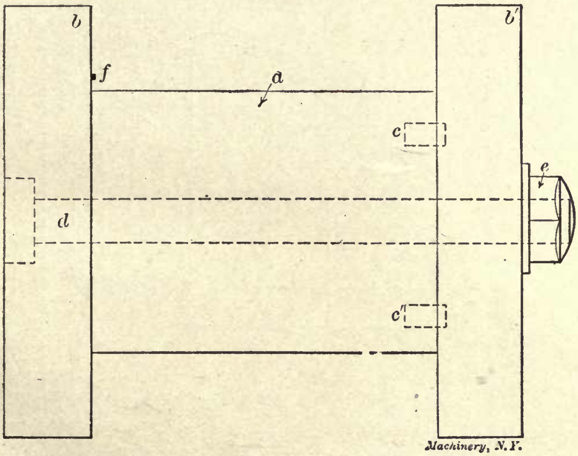


Fig. 50. Form for Winding Field Coils without Spools

to turn out as good work as can be purchased from electric manufacturing companies.

Repairing Field Coils

Fig. 50 gives a view of a form for winding coils that have no spools. The shape of this form depends on the style of the coil to be wound. The form is clamped to a lathe face-plate either by bolts extending through the form or through the side *b*. Dowel pins *c* and *c′* serve to

hold the side *b'* from twisting, and the bolt *d* and the nut *e* hold the whole form together. Fig. 51 represents a guide that is held in the tool-post of a lathe. Attached to the piece *a* is a grooved wheel, *b*, over which the wire from the reel runs. The same arrangement of reels can be employed in winding field coils that is used with armature coils. Fig. 52 shows front and side views of a connector, which consists of a piece of sheet copper, *b*, rolled up at the end, *c*, and sweated

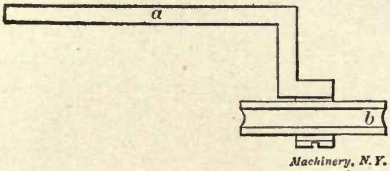


Fig. 51. Guide used in Winding

into a sleeve, *a*, at the opposite end. The sleeve has a set-screw, *d*, for outside connections on the machine.

A very convenient way of securing the last turn of wire is shown in Fig. 53. Here *a*, *b*, *c*, *d*, and *e* represent the convolutions of wire; *f* is a loop of cotton tape with its ends protruding at *g*. The loop is laid on the coil before the turns *c* and *d* are made, then the end of the wire, *h*, is pushed through, and the loop *f* is drawn tight by pulling on the ends at *g*.

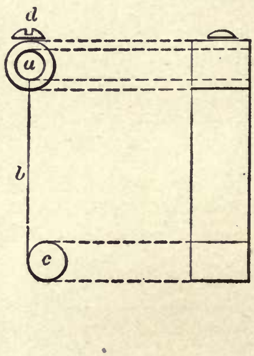


Fig. 52

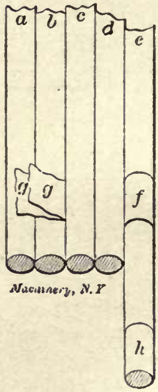


Fig. 53

We will now start to wind a coil. First, bolt the form to the faceplate of the lathe, then arrange the reel conveniently for paying off the wire. Solder a connector like that shown in Fig. 52 to the end of the wire, and tape thoroughly. Catch the connector behind the pin *f*, provided for that purpose (Fig. 50), and proceed to wind. The wire running over a guide wheel in the tool-post enables the operator to use the tool carriage for guiding the wire as it is wound. With a little practice the operator will be able to run the tool carriage backward and forward with enough skill to permit considerable speed in winding.

The connectors can be made in different lengths and widths for varying styles of coils. The connector for the outer end of coil will, of course, be short, allowing the sleeve *a* to come on outside of insulation. Having wound the desired number of turns onto the form, finish the end with a loop of tape, as in Fig. 53, and solder on the outside connector. Coils wound of wire fine enough to be flexible do not require connectors, as the wire itself may be left protruding through the covering. Before starting the winding, several pieces of cord or cotton tape must be laid across the form, with ends long enough to tie over the completed coil. Having completed the winding of coil, take off the side of form, *b'*, and remove the coil. Different manufacturers have various methods of insulating their coils, and it is always well to

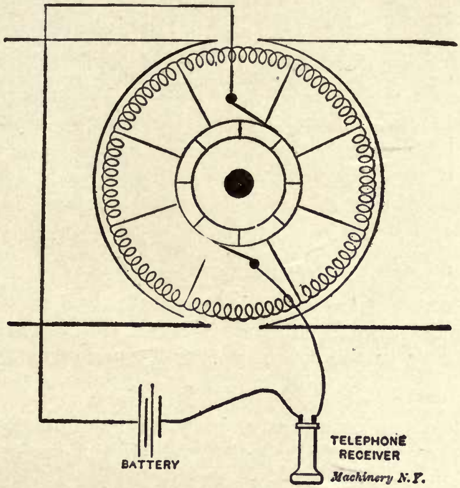


Fig. 54. Testing for Faults in Armature

cover the new coil in the same manner as the original coil was covered.

Tests for Faults in Armature

It is very desirable to be able to locate faults in motor or generator armatures around shops with simple apparatus that may be on hand. A method which has proven very reliable and requires only a few cells of battery and a telephone receiver is given below.

Tests for Open Circuit

Clean the brushes and commutator, and apply current from a few cells of battery having a telephone receiver in circuit as shown in Fig. 54. If the machine has more than two brushes, connect the leads to two adjoining brushes and raise the balance. Now rotate the armature slowly by hand and there will be a distinct click in the receiver as each segment passes under the brushes until one brush bears on the segment at fault, when the clicking will cease. Note that the brushes must not cover more than a single segment.

If on rotating the armature completely around, the receiver indicates no break in the leads, connect the battery leads directly to the brushes, as shown in Fig. 55, and touch the connections from the receiver to two adjacent bars, working from bar to bar. The clicking

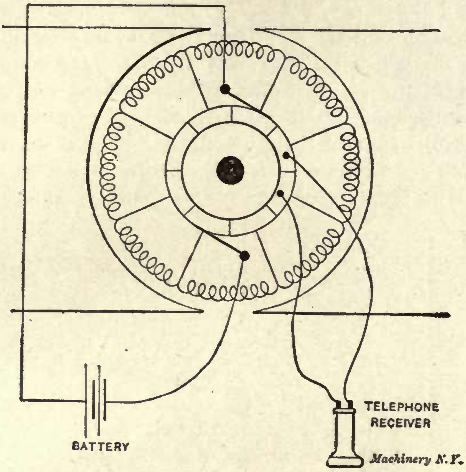


Fig. 55. Next Step in Testing Armature

should be substantially the same between any two commutator bars; if the clicking suddenly rises in tone between two bars, it is indicative of a high resistance in the coil or a break (open circuit).

Test for Short Circuit

Where two adjacent commutator bars are in contact, or a coil between two segments becomes short-circuited, the bar-to-bar test just

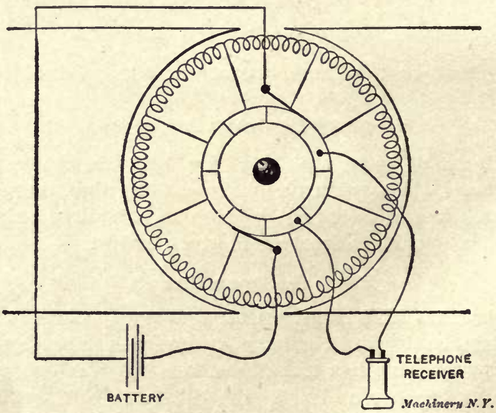


Fig. 56. Test for Short Circuit

described will detect the fault by the telephone receiver remaining silent. If a short circuit is found, the leads from the receiver should

then include or straddle three commutator bars, as shown in Fig. 56. The normal click will then be twice that between two segments until the coils in fault are reached, when the clicking will be less. When this happens, test each coil for trouble and, if individually they are all right, the trouble is between the two.

Test for Grounded Armature

Place one terminal of the receiver on the shaft or frame of the machine, and the other on the commutator. If there is a click it indicates a ground. Move the terminal about the commutator until the least clicking is heard and at or near that point will be found the contact. Grounds in field coils can be located in the same manner.

CHAPTER VI

WINDING OF DIRECT-CURRENT ARMATURES*

The following detailed description by Mr. A. C. Jordan, of the various operations performed by an armature winder, accompanied by precise directions and data, originally appeared in the *Electric Journal*, December, 1905, and was published in MACHINERY, March, 1906. The

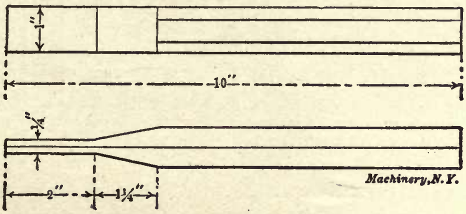


Fig. 57. Wedging Tool

types of armatures to which this description applies are those used in direct-current railway motors, crane and hoisting motors, vehicle motors, bipolar motors and belted generators up to 100 kilowatt.

Tools

The tools used by an armature winder are as follows:

1 shoe knife,
1 pair seven-inch shears,
1 pair eight-inch pliers,
1 ten-inch screw-driver,
1 three-pound rawhide mallet,
1 small steel riveting hammer,
1 wedging tool (See Fig. 57),
1 heavy steel drift (See Fig. 58),
Also an assortment of fiber drifts of varying width. length and thickness (See Fig. 59).

* MACHINERY, March, 1906.

The rawhide mallet is used in driving the coils into the slots by means of the fiber drifts, and in bending the coils into shape. The steel hammer is used for straightening laminations or fingerplates. It should never be used in bending coils or on any of the drifts. The wedging tool made from a cold chisel is used in driving wedges into the slots as a hammer would injure the insulation of the coils and might bend the laminations.

Core

An armature core is built up of soft sheet steel laminations. These are stamped of the desired shape and carefully annealed. The stampings are then built up, and keyed to a shaft or spider and held securely in place by end plates. Ventilating spaces are left next to the shaft or spider and air ducts are distributed at intervals through the punchings by putting in spreaders to hold the laminations apart. The armature

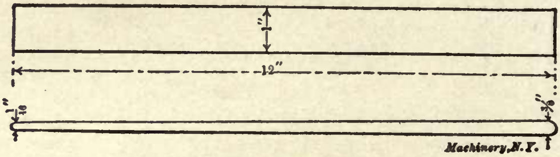


Fig. 58. Steel Drift

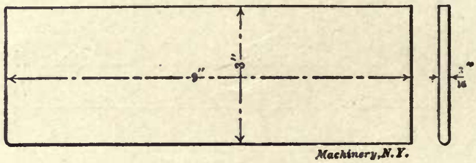


Fig. 59. Fiber Drift

in rotating draws in air through the ventilating spaces next to the shaft and forces it out through the ducts, thus furnishing a simple and effective means of ventilation. After the core is assembled, the slots are filed to remove any projecting burrs; if these were not removed, the insulation of the coil might be torn when a coil is driven into the slot and cause grounds and short circuits in the winding.

Operations before Placing Coils on the Core

The core is mounted in a winding lathe, as shown in Fig. 60. If duck blankets are used they should be placed on the shaft before the core is placed in the winding lathe. If a block is used on the rear end of the armature core to shape the coils as they are wound or to protect the cast-iron end-bell, the block should be placed on the shaft before mounting in the lathe so that it will not be necessary to remove the core after it is partly wound. The core should be placed in the lathe with the commutator end at the winder's left. The commutator end of an armature may be distinguished by the key-way cut in the shaft next to the core for the commutator key; also on railway armatures the shaft opposite the commutator end is beveled and threaded to fit the pinion as in Fig. 61.

A description of the winding of what is known as a No. 38 B railway motor will be given in detail:

The core of this armature is built on the shaft and has three ventilating ducts parallel to the shaft. There are 45 slots. These slots are relatively narrow as compared with the width of the teeth. It will be seen from Fig. 64 that the end plate of the commutator end fits

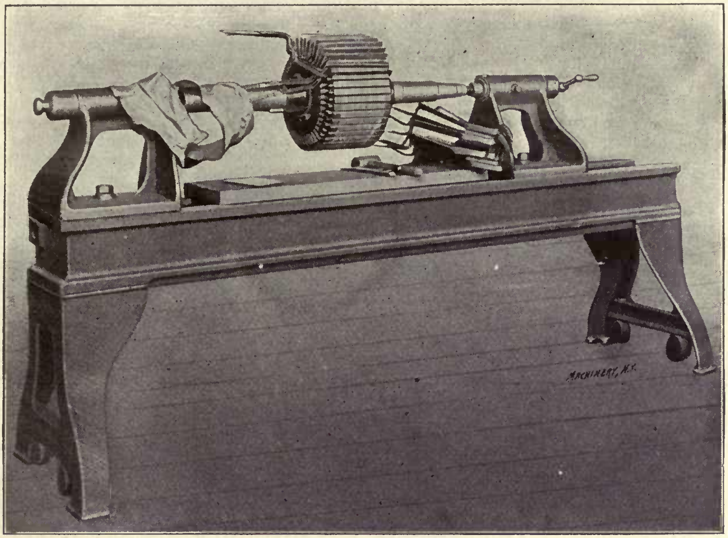


Fig. 60. Winding Lathe

against a shoulder turned on the shaft. The rear end plate is held in position by a nut which is screwed on to the shaft and held in place by a set-screw. Two duck blankets are used on this armature. They should be placed on the shaft with the wider side of the blanket out and with the seam toward the core. The core should be inspected to see whether any of the laminations or fingers project into the slots.

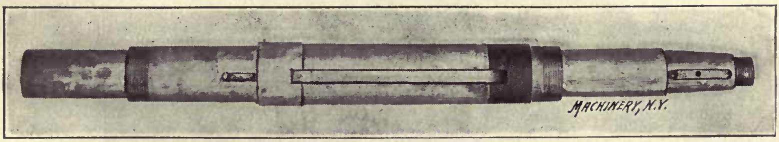


Fig. 61. Armature Shaft

The steel drift and rawhide mallet are used to clear the slot of any of these projections.

Cells

In each slot are placed cells of paraffined express paper. They are made of such a width that when folded and placed in the slots the edges will project above the core, and thus protect the coils as they are placed in the slots. The cells are stiff enough so that when bent

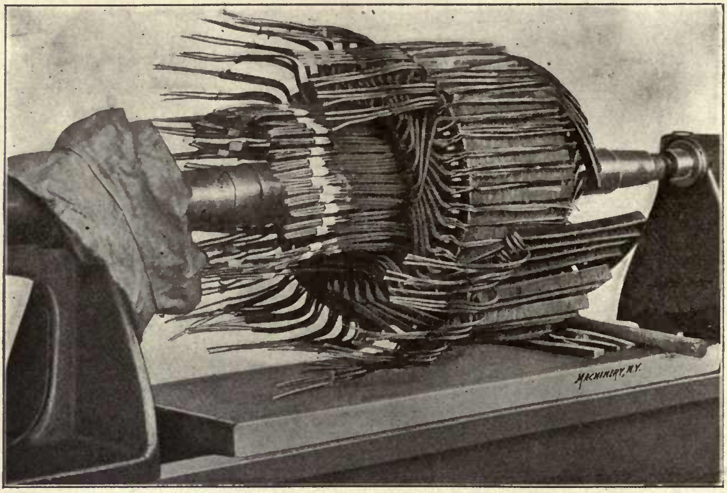


Fig. 62. Inserting the Coils

into the slots they are not easily shaken out, as the armature is revolved in winding. If any cells are longer than the slots they should be cut off so that both ends of the cells will be flush with the ends of the slots.

Coils

In winding this armature, 45 complete coils are used. Each coil, *i. e.*, complete coil (See Fig. 65), is made by assembling in a cell three individual coils each consisting of two turns of No. 9, double cotton-covered wire. Each slot contains one side of each of two different coils.

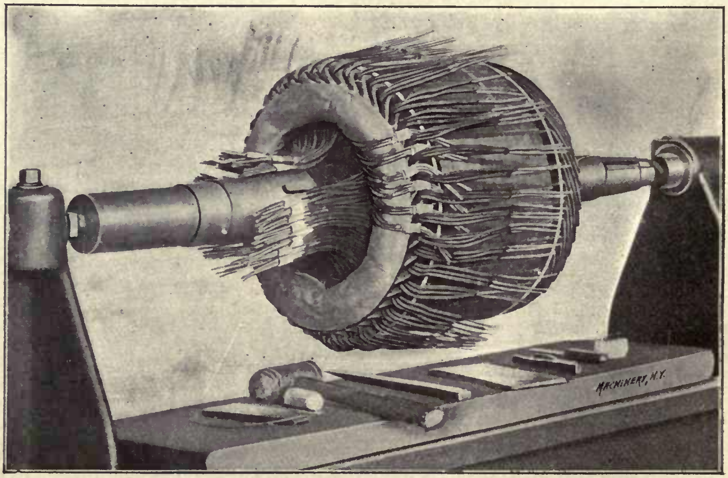


Fig. 63. Fitting the Canvas Blanket

One side of a coil is put in the bottom of one slot and the other side in the top of another slot. Three wires or leads are brought out from each side of the coil on the under side. This type of coil is known as a "three-lead coil."

Taping

The middle lead of the three coming from the bottom side of the coil is taped with black tape, the outside lead is taped with white tape,

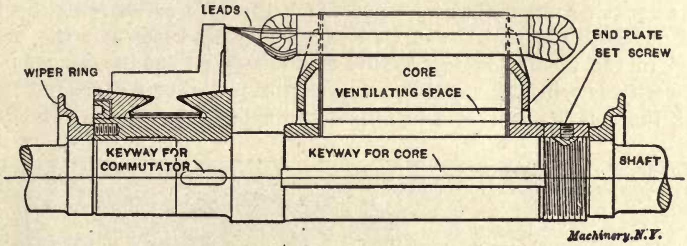


Fig. 64. Section through Armature

and then all three leads are taped together. The top leads are not taped but are bent up and outward, as shown in Fig. 62.

Putting Coils in the Slots

Beginning with any slot the bottom of a coil is placed in it so that each end of the coil is at an equal distance from the core, the top of the coil resting on the core. The bottom of the coil is forced to the bottom of the slot by means of the fiber drift and mallet. Call this slot No. 1, and count toward the top of the coil until slot No. 11 is reached. Start the top of the coil in this slot. This is called a throw

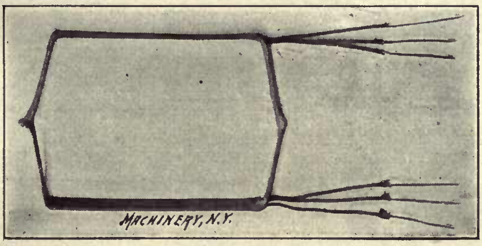


Fig. 65. Armature Coil

of 1 and 11, or simply 11. The tops of the first ten coils are not forced into the slots as they must be taken out when the last ten coils are put in place (See Fig. 62). The bottom of the next coil is placed in slot No. 45, and the top in No. 10. After the first eleven coils are in place the tops should also be driven into the slots. Continue in this manner around the armature until slot No. 11 is reached. Beginning with slot No. 45, take out the tops of all the coils up to and including the one in No. 11 slot and bend them away from the armature so that the bottom sides of the last ten coils can be placed in the slots. After the last ten coils have been placed in position, the tops of the coils

which were removed to make place for the last ten coils are put in place.

A piece of heavy wire is wrapped around the coils at each end just outside of the core and tightened with the pliers as firmly as possible. This is to hold the coils in the slots while the winding is being tested, trued and connected. If the upper leads are not bare at the outer ends, the insulation should be scraped from them for about three inches. All the upper leads are then connected by a fine copper wire. Care must be taken that no leads touch the core or shaft as the leads are not required to be insulated sufficiently to withstand the voltage used in the insulation test. This test consists in applying 3600 volts between the winding and the core. If the test shows a ground in any coil, the coil is removed and a new one substituted.

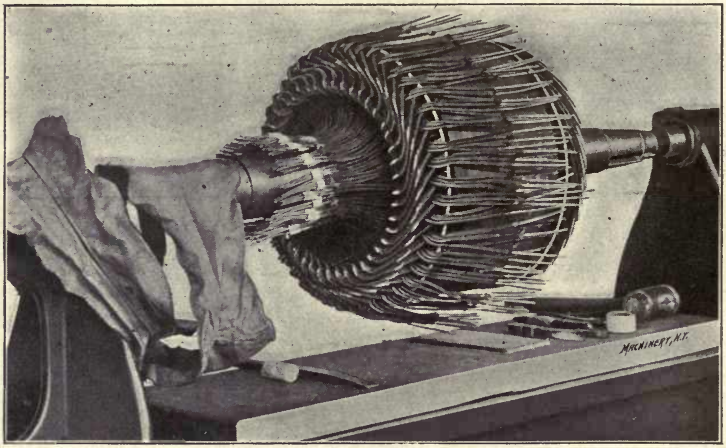


Fig. 66. Truing-up the Winding

After the armature has passed the insulation test, the tops of the slot cells are cut off even with the core. Then the tops and ends of the coils are trued. To do this the armature is revolved in the lathe and a piece of chalk is held so that in turning the armature it will mark the coils that project. These are then driven down, or the others are brought out even with the high ones. The fronts of the coils are then trued. In Fig. 66 parts of the winding being trued are marked with white chalk. The blankets are next fitted over the front ends and sewed on with a curved needle and wax thread. The thread is passed in under the ends of the coils and brought up through them near the core and tied firmly over the blankets. They should be tied in at least six different places. The blankets are to separate and insulate the leads from the ends of the coils after the leads are connected to the commutator (See Fig. 63).

The winder then stands on the opposite side of the lathe and takes the bottom lead of any coil and counts seven slots in a clockwise direction facing the commutator. This lead is bent up and across the ends

of the coils and held in place by the lead from the seventh slot. Proceeding in the same manner around the armature in a counter-clockwise direction facing the commutator, all of the lower leads are bent like the first one and secured by the upper leads. This finishes the operation of winding. The armature is now ready to have a commutator pressed on.

Pressing on Commutator

Small commutators are pressed on to the shaft by a hand press. All of the larger commutators are pressed on by means of a power press. In Fig. 67 is shown a hand press. The plate *B* is used in removing old commutators. It is placed back of the commutator as at *x y* with the slot *C* over the shaft. Bolts *a b* are passed through the holes *a a* in the plate and secured by nuts. The commutator can then be forced

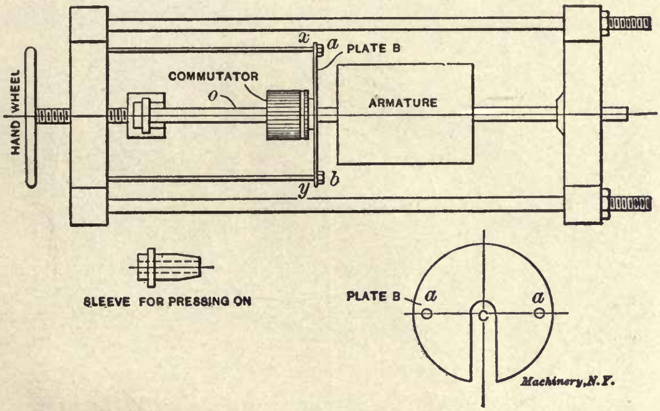


Fig. 67. Press for Forcing on and Removing Commutator

off the shaft. In pressing on a commutator, a sleeve is placed over the shaft at *O*, and rests against the commutator. The rear end of the shaft is secured so it will withstand the pressure, and the commutator is forced on. The power presses are built on the principle of a hydraulic press. In pressing on a commutator a piece of babbitt metal or soft brass should be painted with white lead before having the commutator pressed on, in order to lubricate the shaft so that the commutator will press on easily. The wiper rings are pressed on after the commutator and then the armature is ready to be connected.

Connecting

The first operation necessary in connecting is to "lay-off" the commutator. In "laying-off," the upper and lower leads of any coil are found by means of a lighting-out set. The slots which contain this coil are marked with chalk. In connecting a No. 38 B railway motor armature the following should be noted: There are 135 bars in the commutator. The throw of coil is 1 and 11 and, as the winding is progressive, the commutator throw equals

$$\frac{\text{number of bars} + 3}{2} = 69, \text{ or } 1 \text{ and } 69.$$

With this commutator throw the center of the throw will be a bar. The throw of a coil is 1 and 11, therefore, the center of a coil throw will be a slot. Hence every slot should line up with a bar. By holding a pencil on the commutator perpendicular to it and sighting along the side of a coil the bar opposite the center of the slot in which the side lies may be located as at *A* in Fig. 68. Mark this bar with a colored pencil. Find the bar opposite the other side of the coil, as at *B*, and mark with the pencil, calling the slot in line with *A*, No. 1.

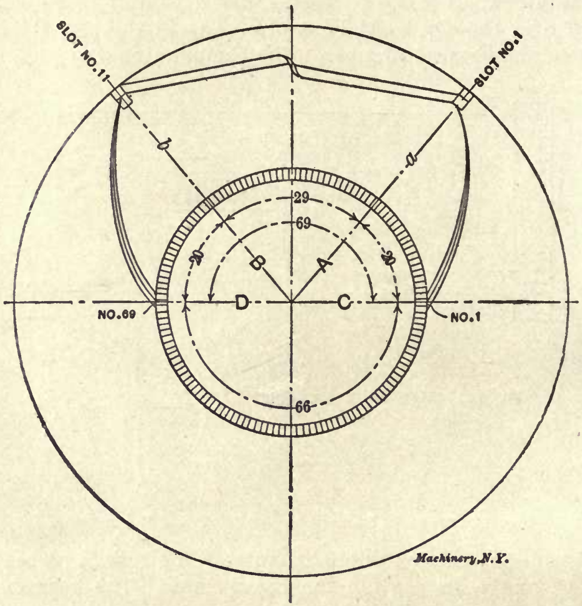


Fig. 68. Armature Correction Diagram

Count 20 bars from *A*, in a clockwise direction and mark this bar No. 1. Also count 20 bars from *B* in a counter clockwise direction and mark this bar No. 69. Count from this bar to and including bar No. 1 and there should be 69 bars. Also there should be 29 bars between *A* and *B*. *D B A C* is called the forward throw and *D C* is the back throw. It is seen that the back throw is 66 or three less than the forward, as it always will be in a four-pole, progressive wave-wound armature. If an armature is wound retrogressively the forward and back throws differ by one. If, in laying-off, the center of the slot does not come in line with a bar, find one that will line up with a bar and proceed as above.

The 38 B armature has three leads on each side of a coil and as there are 135 bars, there is no idle coil in this winding. Place the middle lead of the three coming from the bottom of slot No. 1 in bar

No. 1, the outside lead in bar No. 135 and the inside lead in bar No. 2. Next take the lower leads from slot No. 2 and place them in bars Nos. 3, 4, and 5. The insulation should be removed from the leads where they are to be soldered to the commutator necks. They are driven to the bottom of the slot by means of a tool similar to the wedging tool only much thinner. The lower leads are all placed in the commutator and then they are "lighted-out."

Lighting-out

The purpose of lighting-out is to see that there are no grounds or short circuits between the bars or coils, and to see if the leads are connected to the proper bars. The lighting-out set consists of two terminals connected in series with a 110-volt incandescent lamp to the 110-volt service lines.

One terminal of the lighting-out set is placed on bar No. 1 and the other on the middle lead coming from the top of the same coil. The lamp

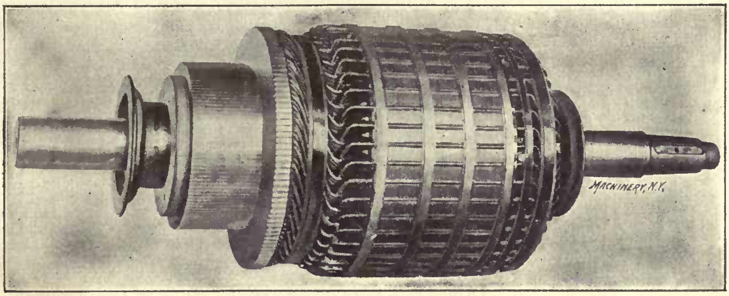


Fig. 69. The Completed Armature

should light. Next move the terminal on commutator bar No. 1 to bar No. 2 and if the lamp lights it shows a short circuit between bars or between coils. If the lamp does not light the upper terminal is moved to the next lead counter-clockwise, when the lamp should light; if not, find the bar on which it will light and bring the wire connected to that bar to the proper bar. Continue in this manner around the commutator. After the winding is lighted-out, the ends of the leads projecting out over the commutator beyond the neck are cut off and saved, as they are to be used again.

Two layers of friction cloth are then wound over the lower leads and then the upper leads may be connected. The center lead from slot No. 11 is connected to bar No. 69, the outside lead is connected to bar No. 70, the inside lead from slot No. 12 is connected to bar No. 71, and so on around the armature. After the leads are placed in the slots in the commutator necks, they are driven to the bottom of the slots. The lower leads which were cut off are known as "dummies." These are driven into the tops of the slots until the slots are full. After putting in the dummies, all projecting ends are cut off and the armature is tested for grounds and short circuits. The leads are then soldered in the slots and the armature is then ready for banding.

Banding

Tinned steel wire is used in banding. The bands on the core are insulated with mica and fullerboard while on the coils they are insulated with Japanese paper and tape. The insulation is made wide enough so that it projects one-eighth of an inch on each side of the bands. The bands on the core and lead are five-eighths of an inch wide, while the ones on the ends of the coils are made as wide as possible. In putting on the bands the armature is rotated in a lathe and the steel wire is wound on under tension. Clips are placed under the band wires and after sufficient turns have been wound on, the clips are bent over the wires and soldered to them, so that the band wires are held firmly together. After the bands are all on, they are heated with a soldering iron and solder run around each band. Thus the wire and clips are all held firmly in place.

Seven strips or bands are placed on the armature, four on the core, one on each end of the coils and one to hold the leads in place. These are shown in Fig. 69. The two bands on the rear end of the coils are connected to the last band on the core by means of three anchor clips spaced equally around the armature. This is done so there will be no danger of the outer bands slipping. After the armature is banded it is tested for short circuits or grounds, given a coat of insulating paint and is then ready for assembling with the other motor parts.

CONTENTS OF DATA SHEET BOOKS

No. 1. Screw Threads.—United States, Whitworth, Sharp V- and British Association Standard Threads; Briggs Pipe Thread; Oil Well Casing Gages; Fire Hose Connections; Acme Thread; Worm Threads; Metric Threads; Machine, Wood, and Lag Screw Threads; Carriage Bolt Threads, etc.

No. 2. Screws, Bolts and Nuts.—Fillister-head, Square-head, Headless, Collar-head and Hexagon-head Screws; Standard and Special Nuts; T-nuts, T-bolts and Washers; Thumb Screws and Nuts; A. L. A. M. Standard Screws and Nuts; Machine Screw Heads; Wood Screws; Tap Drills; Lock Nuts; Eye-bolts, etc.

No. 3. Taps and Dies.—Hand, Machine, Tapper and Machine Screw Taps; Taper Die Taps; Sellers Hobs; Screw Machine Taps; Straight and Taper Boiler Taps; Stay-bolt, Washout, and Patch-bolt Taps; Pipe Taps and Hobs; Solid Square, Round Adjustable and Spring Screw Threading Dies.

No. 4. Reamers, Sockets, Drills and Milling Cutters.—Hand Reamers; Shell Reamers and Arbors; Pipe Reamers; Taper Pins and Reamers; Brown & Sharpe, Morse and Jarno Taper Sockets and Reamers; Drills; Wire Gages; Milling Cutters; Setting Angles for Milling Teeth in End Mills and Angular Cutters, etc.

No. 5. Spur Gearing.—Diametral and Circular Pitch; Dimensions of Spur Gears; Tables of Pitch Diameters; Odontograph Tables; Rolling Mill Gearing; Strength of Spur Gears; Horsepower Transmitted by Cast-iron and Rawhide Pinions; Design of Spur Gears; Weight of Cast-iron Gears; Epicyclic Gearing.

No. 6. Bevel, Spiral and Worm Gearing.—Rules and Formulas for Bevel Gears; Strength of Bevel Gears; Design of Bevel Gears; Rules and Formulas for Spiral Gearing; Tables Facilitating Calculations; Diagram for Cutters for Spiral Gears; Rules and Formulas for Worm Gearing, etc.

No. 7. Shafting, Keys and Keyways.—Horsepower of Shafting; Diagrams and Tables for the Strength of Shafting; Forcing, Driving, Shrinking and Running Fits; Woodruff Keys; United States Navy Standard Keys; Gib Keys; Milling Keyways; Duplex Keys.

No. 8. Bearings, Couplings, Clutches, Crane Chain and Hooks.—Pillow Blocks; Babbitted Bearings; Ball and Roller Bearings; Clamp Couplings; Plate Couplings; Flange Couplings; Tooth Clutches; Crab Couplings; Cone Clutches; Universal Joints, Crane Chain; Chain Friction; Crane Hooks; Drum Scores.

No. 9. Springs, Slides and Machine Details.—Formulas and Tables for Spring Calculations; Machine Slides; Machine Handles and Levers; Collars; Hand Wheels; Pins and Cotters; Turn-buckles, etc.

No. 10. Motor Drive, Speeds and Feeds, Change Gearing, and Boring Bars.—Power required for Machine Tools; Cutting Speeds and Feeds for Carbon and High-speed Steel; Screw Machine Speeds and Feeds; Heat Treatment of High-speed Steel Tools; Taper Turning; Change Gearing for the Lathe; Boring Bars and Tools, etc.

No. 11. Milling Machine Indexing, Clamping Devices and Planer Jacks.—Tables for Milling Machine Indexing; Change Gears for Milling Spirals; Angles for setting Indexing Head when Milling Clutches; Jig Clamping Devices; Straps and Clamps; Planer Jacks.

No. 12. Pipe and Pipe Fittings.—Pipe Threads and Gages; Cast-iron Fittings; Bronze Fittings; Pipe Flanges; Pipe Bends; Pipe Clamps and Hangers; Dimensions of Pipe for Various Services, etc.

No. 13. Boilers and Chimneys.—Flue Spacing and Bracing for Boilers; Strength of Boiler Joints; Riveting; Boiler Setting; Chimneys.

No. 14. Locomotive and Railway Data.—Locomotive Boilers; Bearing Pressures for Locomotive Journals; Locomotive Classifications; Rail Sections; Frogs, Switches and Cross-overs; Tires; Tractive Force; Inertia of Trains; Brake Levers; Brake Rods, etc.

No. 15. Steam and Gas Engines.—Saturated Steam; Steam Pipe Sizes; Steam Engine Design; Volume of Cylinders; Stuffiing Boxes; Setting Corliss Engine Valve Gears; Condenser and Air Pump Data; Horsepower of Gasoline Engines; Automobile Engine Crankshafts, etc.

No. 16. Mathematical Tables.—Squares of Mixed Numbers; Functions of Fractions; Circumference and Diameters of Circles; Tables for Spacing off Circles; Solution of Triangles; Formulas for Solving Regular Polygons; Geometrical Progression, etc.

No. 17. Mechanics and Strength of Materials.—Work; Energy; Centrifugal Force; Center of Gravity; Motion; Friction; Pendulum; Falling Bodies; Strength of Materials; Strength of Flat Plates; Ratio of Outside and Inside Radii of Thick Cylinders, etc.

No. 18. Beam Formulas and Structural Design.—Beam Formulas; Sectional Moduli of Structural Shapes; Beam Charts; Net Areas of Structural Angles; Rivet Spacing; Splices for Channels and I-beams; Stresses in Roof Trusses, etc.

No. 19. Belt, Rope and Chain Drives.—Dimensions of Pulleys; Weights of Pulleys; Horsepower of Belting; Belt Velocity; Angular Belt Drives; Horsepower transmitted by Ropes; Sheaves for Rope Drive; Bending Stresses in Wire Ropes; Sprockets for Link Chains; Formulas and Tables for Various Classes of Driving Chain.

No. 20. Wiring Diagrams, Heating and Ventilation, and Miscellaneous Tables.—Typical Motor Wiring Diagrams; Resistance of Round Copper Wire; Rubber Covered Cables; Current Densities for Various Contacts and Materials; Centrifugal Fan and Blower Capacities; Hot Water Main Capacities; Miscellaneous Tables: Decimal Equivalents, Metric Conversion Tables, Weights and Specific Gravity of Metals, Weights of Fillets, Drafting-room Conventions, etc.

MACHINERY, the monthly mechanical journal, originator of the Reference and Data Sheet Series, is published in three editions—the *Shop Edition*, $1.00 a year; the *Engineering Edition*, $2.00 a year, and the *Foreign Edition*, $3.00 a year.

The Industrial Press, Publishers of MACHINERY,

49-55 Lafayette Street, New York City, U. S. A.